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ABSTRACT

The energy manpower research project was established to review the process used to identify skills needed in emerging energy sources and to discover any new occupations for which additional post-high school, vocational/technical training would be needed. A supplemental part of the project was the development of a solar energy instructional module. In the investigative work, energy sources examined were coal, gasification, geothermal, nuclear, solar, waste products, and wind. Arizona and New Mexico employers were interviewed concerning energy policies and manpower needs. Respondents cited lack of a federal energy policy as the greatest deterrent to alternative energy sources development. Job titles provided by employers generally referred to conventional trades, such as pipefitter, electrician, and welder. (Appendixes include interview materials, lists of perceived existing and emerging policies, and manpower needs for operation of two coal-fired generating plants. The remainder of the report is primarily devoted to the presentation of the solar energy instructional module. Also reviewed are module preparation procedures and evaluations. The module is divided into seven units: using solar energy, locating the sun, solar energy systems, collections, storage, distribution, and representative solar energy systems for heating homes. Units contain objectives, terms and definitions, information sheets, activities, assignment sheets, tests, answers, and references.) (Author/CSS)

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Final Report

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Policies and Manpower Needs Related to Emerging Energy Sources in Arizona and New Mexico

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August 15, 1977

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Table of Contents

SECTION I - Policies and Manpower Needs Related to Emerging Energy Sources in Arizona and New Mexico - Everett D. Edington, Laurie Keaton, and Yousif Neberay

SECTION II - Instructional Module in Solar Energy

A. Procedure Followed in Preparing the Instructional Units

B. Evaluations of Solar Energy Module

C. Solar Energy Instructional Module - "Understanding Solar Energy Systems" Laurie Keaton, Everett D. Edington

Abstract

The purpose of the Energy Manpower Research Project was to identify what skills would be needed in emerging energy sources and to discover any new occupations for which additional post-high school, vocational/technical training would be needed. Manpower needs were projected for the next 5 to 10 years, and energy policies were considered in attempting to identify those emerging energy sources which held the most promise for development within the next 10 years. The energy sources under investigation were coal gasification, geothermal, nuclear, solar, waste products, and wind.

To obtain the desired information, an interview schedule was used. Interviewers visited employers in Arizona and New Mexico and recorded their responses to questions about energy policies and manpower needs. The information obtained represents the perceptions of employers and researchers about policies and manning needs.

Respondents cited the lack of a Federal energy policy as the greatest deterrent to the rapid development of alternative energy sources. Other policies discussed included that government policies providing monetary assistance, especially through tax incentive programs, be expanded; that problems associated with existing environmental regulations and changes in regulations be resolved; that the general public be educated about how solar energy can best be utilized; that prices on conventional fuels be set to cover the actual costs; that natural gas be deregulated; and that policies promoting an integration of alternative energy sources with existing industries should be explored.

In most cases, the job titles provided by employers referred to conventional trades and skills. Those trades most in demand for construction of coal gasification and nuclear generating plants are as follows: pipefitter, electrician, welder, boilermaker, carpenter, ironworker, and operating engineer. The solar industry appears promising as a new industry. Workers in the solar industry will need some training in a combination of skills, such as sheet metal work, carpentry, welding, and pipe fitting. A basic understanding of systems theory will be needed by engineers, sales personnel, and installers and servicemen in the solar industry. Utilization of waste products and wind as energy sources are still in the research stage, making manpower projections difficult. Geothermal energy is being developed, but it is expected that manpower needs will be satisfied by movement of workers to those jobs from jobs in the petroleum industry.

Table of Contents

Abstract ii
List of Tables v

I. Introduction 1
Previous Studies 1
Objectives 3
Procedure 4
The Interview Schedule 5
Population and Sampling 5
Collecting the Data 7

II. Policies Affecting Energy Development 11
Coal Gasification 12
Existing Policies 12
Suggested and Emerging Policies 13
Geothermal 13
Existing Policies 13
Suggested and Emerging Policies 15
Nuclear 15
Energy Policies 15
Manpower Policies 20
Solar 21
Existing Policies 21
Suggested and Emerging Policies 24
Waste Products 26
Wind 26
National Manpower Policies 27
Conclusions 27

III. Projected Manpower Needs 29
Coal Gasification 30
Geothermal 33
Nuclear 35
Solar 43
Waste Products 50
Wind 51
Conclusion 52

IV. Summary and Recommendations 55
Procedure 55
Energy Policies 56
Manpower Training Needs 58
Conclusions 68
Recommendations 69
References 71

Appendix A: Advisory Board, Energy Manpower Research Project..... 75
Appendix B: Interview Schedule..... 79
Appendix C: Organizations Interviewed..... 85
Appendix D: Lists of Perceived Existing and Emerging Policies..... 95
Appendix E: Manpower Needs for Operation of Two Coal-Fired Generating Plants.....103

List of Tables

1. Number of Interviews Utilized in the Study..... 7
2. Cost of Electricity, 1975..... 18
3. Cost Projections: 1985-Nuclear..... 18
4. Cost Projections: 1985-Coal..... 19
5. Estimated Technical and Skilled Manpower for a Coal Gasification Plant, Construction... 31
6. Estimated Technical and Skilled Manpower for a Coal Gasification Plant, Operation..... 32
7. Job Title and Projected Number of Employees: Geothermal..... 34
8. Construction of the Palo Verde Nuclear Station: Competencies of Employees..... 36
9. Total Operating Staff: Palo Verde Nuclear Generating Station..... 40
10. Projection of Manpower Needs: Carlsbad Nuclear Waste Disposal Project..... 43
11. Job Titles and Projected Number of Employees: Solar..... 44
12. Manpower Needs, Proposed Solid Waste Generating Plant for Phoenix, Arizona..... 51
13. Waste Product Researchers: New Mexico..... 52
14. Proposed Job Titles in Wind Energy, New Mexico... 53
15. Summary of Manpower Needs by Job Title and Energy Source..... 59

Chapter 1

Introduction

The oil embargo of 1973 brought to the attention of the American people how dependent the United States had become on imported oil. Since that time, efforts have been made to assess the nation's energy needs and supplies. It is more and more apparent that the United States has become heavily dependent on petroleum products as a source of energy. At the same time, domestic supplies of both petroleum and natural gas are diminishing, and this fact has added impetus to the growing interest in developing alternative energy sources. However, if alternative energy sources are to be developed successfully, an adequately trained labor force will be needed.

Previous Studies

Several studies have been made of manpower needs in energy industries, but these studies have focused mainly on national rather than on regional needs. Also, these studies tend to emphasize manpower needs for the more traditional sources of energy.

The United States government initiated Project Independence "to assess the Nation's capability to achieve relative degrees of energy independence from foreign fuel sources" (1974, p. 1). The Labor Task Force was to estimate labor requirements, to identify "shortfalls between labor demands and supplies," and "to recommend action and policies for overcoming such shortfalls" (p. 3, 4). The study was national in character and was focused on the following energy industries: coal, nuclear, petroleum and natural gas exploration and extraction, petroleum refining, gas processing, oil shale, synthetic fuels from coal, and fossil fuel electric power generation. The study found that "the craft posing the greatest likelihood of a labor constraint would . . . be the pipe/steam fitter" (p. 147).

The study concluded that efforts should be made to improve the utilization and distribution of available labor, that information about labor needs should be disseminated, that efforts should be made to encourage job mobility and that efforts should be made to encourage the training of skilled workers to fit new needs. The report did not include regional or local estimates of manpower needs. Regional information was identified as needed. Occupational requirements and projected manpower needs are, in some instances, obtainable from the report on a regional basis. For example,

general labor requirements for uranium exploration, mining, milling, and enrichment and for oil shale production are provided.

The National Commission for Manpower Policy (1975) stressed the need for more study of energy manpower needs:

> Where special and unique manpower requirements arise from new energy initiatives, these needs must be identified so that the involved agencies and the manpower authorities can take the necessary steps to insure that the required manpower will be available where it is needed on a timely basis (p. 20).

The Commission pointed out that although many agencies were planning to study certain aspects of energy manpower, substantial gaps existed between what each of these agencies planned to study (p. 15). There was also some concern that each agency appeared to be making its own assumptions concerning future energy policies and planned only to deal with developments which would have impact on the sponsoring agency. As a result of this somewhat fragmented approach, there is a need to assemble information that will answer basic questions concerning the overall impact of emerging energy policies and programs upon a particular geographic area.

The Bechtel Power Corporation has prepared a series of reports for the Energy Research and Development Administration (ERDA) on manpower requirements for energy production. Direct Requirements of Capital, Manpower, Materials and Equipment for Selected Energy Futures (Gallagher, et al., 1976) examines five possible energy futures and attempts to project direct requirements for construction and operation of energy producing facilities in each possible future. The report first projects needs if the United States has access to limited petroleum imports and, second, if there is unlimited importation of petroleum. The report then extends the limited imports future to cover three possible scenarios: the Synthetic Fuels Case (in which energy would largely be obtained from coal, gas, oil shale, coal liquids, and municipal wastes augmented by coal); the Combinations Case (in which solar, solid waste and coal, and geothermal would be utilized); and the Nuclear Moratorium Case. Manpower needs for each possible future are projected, both for construction and for operation. As in the case of Project Independence, the study is national in scope.

In the second study, (Gallagher and Teather, 1976), projected needs for skilled laborers are examined. The report is a qualitative overview; the results reported were obtained from information supplied by Bechtel's senior labor relations personnel. The emphasis is primarily directed towards manpower needs for power plant construction, but projections are broken down by region. The Southwestern states were reported as having 40 to 50 percent unemployment in the construction industry (Gallagher and Teather, 1976, p. 3-3). Even in a slump period, shortages were noted in certain crafts which were judged essential to a project schedule. Electricians, pipefitters (including welders), and boilermakers (including welders) were identified as critical crafts in which there were shortages; in the Southwest the greatest shortages were specified to be for pipefitters and boilermakers, both including welders, (Gallagher and Teather, 1976, pp. 3-3, 4).

Thus some manpower needs surveys for energy producing industries have been done. It should be noted, however, that these surveys have concentrated largely on the traditional energy producing industries and are not specific to Arizona and New Mexico. The purpose of the present study is to examine the feasibility of and assess the manpower needs relative to the development of alternative energy sources in the two-state area.

Objectives

The Energy Manpower Research Project was established to determine what skills would be needed and to identify where new skills or training might be needed in developing alternative energy sources in New Mexico and Arizona. The major purpose of the study was to aid those persons involved in manpower training programs in Arizona and New Mexico to identify emerging occupations and plan for implementation in post-secondary occupational training programs. It is hoped the study will enable manpower specialists and vocational educators to better plan for providing trained manpower in emerging energy occupations. The following objectives were proposed:

1. Determine how emerging national and local energy policies affect manpower needs in the Southwest.

2. Identify emerging energy sources in the Southwest.

3. Identify possible manpower needs in each emerging energy field.

4. Identify levels of training needed for each identifiable occupation.

The area under study was limited to New Mexico and Arizona. The emerging energy sources examined were solar, wind, and geothermal (considered individually); waste products, such as animal wastes, sewage and garbage; nuclear power generation; and coal gasification.

Although, initially, nuclear fuel had been excluded from the study, the projected manning needs for nuclear power generation and nuclear waste storage in the two-state area are included in these findings. Manning tables for two coal-fired generating stations are provided in an appendix. The increase in number of nuclear and coal-fired plants will have an impact on the availability of technicians who might otherwise seek employment in emerging alternative energy industries.

The time frame for the study was limited to ten years. It was thought that projections for manpower needs beyond 1986 would be unreliable.

At present, many emerging policies have not been settled. Extensive development of any of the energy sources listed above is dependent on existing or emerging energy policies at the state and national level. Because state or Federal policies can affect the development of a specific energy source, it was thought time should be devoted to a study of policies relating to the development of the various energy sources.

Procedure

In order to achieve the study objectives related to objectives one through four, the following steps were followed:

1. An advisory committee was selected.
2. An interview schedule was prepared.
3. The interviewers were trained.
4. Governmental agencies, university research centers, and research laboratories in Arizona and New Mexico were contacted.
5. Private businesses in energy industries were identified.
6. Researchers and businessmen in the private sector were interviewed.

The initial step for the project was to select an advisory board and to meet with the board. The purpose of the meeting was to determine how the survey could best be conducted and who should be contacted in the survey. The advisory board was selected to represent all facets of emerging energy industries in the two-state area. Members of the advisory board are listed in Appendix A.

The Interview Schedule. The schedule completed by interviewers when contacting researchers and businessmen working in energy industries is exhibited in Appendix B. When reviewing the literature, a similarity in approach had been noted between William Stevenson's (1965) "A Study of Employment Opportunities and Training Needs in Off-Farm Agricultural Occupations in Oklahoma" and the present study. In the study made by Stevenson, 719 employers were interviewed, and employment needs and job competencies were projected for a five-year period. Because the schedule developed for that study had been pretested and then used extensively, it was decided to modify that schedule and use it for gathering information in the present energy study.

Questions asked during the interviews were used to determine areas of concern in emerging energy sources. The questions were intended to obtain information about the company interviewed, about government policies, about projections of future manpower requirements, and about other sources which could provide needed information.

After the schedule was prepared, it was presented to a panel of experts to insure the content validity of each question. The panel of experts consisted of members of the Energy Manpower Research Project Advisory Board. Observations and comments offered by advisory board members were used to refine the final format of the schedule.

Population and Sampling. The target population was defined to be all private and public agencies and organizations which have some concern in emerging energy sources in the states of New Mexico and Arizona. However, a sampling procedure was used when the number of potential respondents was large.

Lists of all organizations and individuals involved in any kind of work connected with emerging energy sources in Arizona and New Mexico were compiled. The lists were obtained from a number of sources, such as the Arizona Solar Energy Directory (November 1976), from the New Mexico Energy Research Resource Registry (NMERRR; December 1975), and from some members of the Energy Manpower Research Project Advisory Board.

In sampling solar energy users, the population was stratified by state, i.e., New Mexico and Arizona. There were 169 solar organizations and agencies identified in Arizona and 51 in New Mexico. It was decided to make a random sample of 15 percent of the organizations in Arizona and 45 percent of the organizations in New Mexico. The organizations were arranged alphabetically and numbered accordingly, from one to the last number in the list for each state. Utilizing a random sample table, organizations within each list were randomly selected as their number appeared until a 45 percent ceiling for New Mexico and a 15 percent ceiling for Arizona were reached.

The solar organizations interviewed represented all phases of the solar industry. Included in the sample were architects, consulting engineers, solar equipment distributors and marketing firms, manufacturers of collectors, and research and development personnel.

Of the 19 organizations and agencies identified as involved in geothermal energy in New Mexico, 50 percent were randomly sampled. Because of Arizona's existing moratorium on geothermal land leases, very few geothermal energy respondents were identified in that state. All available organizations and individuals working in geothermal energy in Arizona were contacted.

The two companies which are known to be drilling wells (one firm in each state) were contacted, and both companies granted interviews. Other respondents represented organizations engaged in exploration for sites of geothermal activity and geothermal lease holders. One respondent was engaged in studying alternative uses of geothermal energy: for greenhouses, fisheries, and so on.

Six utility companies were contacted and five granted interviews: Public Service Company of New Mexico, El Paso Electric, El Paso Natural Gas, Salt River Project, and Arizona Public Service.

Also, Los Alamos Scientific Laboratory, Sandia Scientific Laboratory, and White Sands Missile Range were contacted as representing the total population of research laboratories. All available agencies and organizations that showed an interest in coal gasification and the use of waste products and wind power were approached in both New Mexico and Arizona. The waste products being considered for use as energy sources are animal wastes, sewage, and garbage from city landfill operations. Two of the companies contacted were engineering consulting firms.

Table 1 enumerates the number of interviews by energy source conducted for this study. The organizations interviewed are listed in Appendix C.

Table 1

Number of Interviews Utilized in the Study

Energy Source	Arizona	New Mexico	Other*	Total
Coal Gasification			1	1
Geothermal	5	5	2	12
Nuclear	1	3	1	5
Solar	25	25		50
Waste Products	5	2		7
Wind		2		2
Total	36	37	4	77

*This column refers to organizations from Texas and California which function in New Mexico and Arizona.

Collecting the Data. The preliminary contact with the intended participants in the study was made by mail. In most cases, the letter simply stated dates when the interviewer would be in the area and expressed the hope that when the interviewer called an interview could be arranged. A summary of one page explaining the purposes, objectives and approach utilized in the study was enclosed with the letter. This approach proved quite successful. However, with the large utility companies and the research laboratories, the interviewers made more extensive arrangements to insure that interviews were arranged with suitable representatives of the organizations.

Three interviewers were employed for the collection of data. Meetings and training sessions were held to insure continuity of method in collecting data. "One of the best ways of increasing reliability and validity of observations lies in the training of observers" (Sax, 1968, p. 212). To familiarize the interviewers with the field procedure to be followed, all members of the interviewing group attended the interview sessions with the first two respondents.

Members of the interviewing group held frequent meetings to coordinate their activities. The group discussed strategies, approaches, problems and field experiences and formulated tentative solutions to some tactical problems. Because of such exchanges, a minor modification was introduced in the method of approach. In the beginning, the planned approach was to contact each respondent through a telephone

call inviting him/her to participate in the study and to follow this call by a letter and a second telephone call. This procedure was later superseded by dropping the first telephone call and retaining the other steps. When necessary, a second or a third telephone call was made after the initial contact.

The interview method consisted of going through the schedule of questions with each interviewee and noting any relevant remarks that he/she made as each question was asked. Interviewers supplied clarifications whenever they were needed. Each interview session lasted from one-half to one hour. Interview questions were broadly structured, allowing each respondent to express and explain his/her views.

Five months were spent in gathering data from the two states of Arizona and New Mexico (September 1976 to February 1977). Interview schedules were assigned to each interviewer on the basis of personal preference. For example, one interviewer might be more acquainted with one geographic area than with another area.

Generally speaking, only one person was interviewed at a time. In two situations, the interviewer was informed that the interview could take place only in a group meeting. One such interview was conducted in a large research and development organization and the other with a utility company.

A majority of the organizations contacted responded favorably to the invitation to participate in the study. Two declined to participate; one of them turned down the request because the interviewer arrived at a bad time. Two failed to reply and ignored the researcher's requests that a suitable time for an interview be designated.

Although five people were approached who worked in wind energy, only one person was actually interviewed. The three people who refused to be interviewed stated that wind power was not within their areas of expertise, although they were listed in the New Mexico Energy Research Resource Registry (December, 1975) as experts in wind power. One researcher did not respond to the request for an interview.

Question 4, a lengthy table, was not completed in 25 forms. Explanations provided for not completing the table can be summarized as either that the required data was unavailable or that the respondents were unwilling to reveal the information.

It was decided to include in the study those sets of responses which contained answers to at least two questions. The total number of sampled and available participants was 77. The total number of usable participants' responses was 70, thus yielding a response rate of 90.9 percent.

After the projected job titles for the emerging energy industries were collected, experts in the field were consulted to verify the accuracy of the procedure and of the findings. A panel of experts, consisting of members of the advisory board for the Energy Manpower Research Project at New Mexico State University, examined the results and found the work acceptable.

The results of the survey are summarized in the following pages. The findings are separated into two chapters. In Chapter 2, policy is discussed. While generally the findings in Chapter 2 are based on interviews, some information does come from relevant literature and is so identified. In Chapter 3, manpower needs are discussed by energy source. Chapter 4 provides a summary and recommendations.

Chapter 2

Policies Affecting Energy Development

State and Federal policies will affect the development of emerging alternative energy sources. Investments, whether for exploration and drilling for geothermal energy or for building a nuclear or coal gasification plant, are large. Before a company can commit its resources to a single large investment, the company must have adequate assurances that there will be a return on its capital. Likewise, before a young person commits himself to an extensive training period in preparation for his life's work, that person wants some assurances that employment awaits him at the end of the training period. What types of energy sources will ultimately supply the nation's energy needs and thus what types of skills will be in demand will partly depend on what course of action the government chooses to follow. On the national level, various energy scenarios have already been examined and manpower needs projected (Project Independence, 1974; National Commission for Manpower Policy, 1975; Gallagher, et al., 1976).

However, Federal and state policies will have a specific impact on New Mexico and Arizona. For these two states, the development and utilization of solar energy is of especial significance. But Arizona and New Mexico are also areas with significant geothermal resources, coal, and uranium (Grant, 1975; Energy Resources Board, 1977; Arizona Fuel and Energy Office, 1975). Furthermore, both states are experiencing population growth. It can be expected that the energy industries in the two states will grow as energy is needed within the states and as more energy is exported to other states. And, as the energy industries grow, manpower needs will increase. While the industries will grow only if the trained manpower is available to be employed, government policies will affect what kinds of energy industries develop.

> ...a national policy encouraging the use of coal would have a significantly different impact on employment and requirements for skilled manpower than an energy policy aimed at accelerating oil production. In one case, increased numbers of coal miners and mining equipment operators would be needed in Eastern underground mines and for strip mining in the West; and in the case of accelerating the production of oil, persons

> to build and operate offshore drilling rigs and man new refining capacity would be needed in increased quantities (National Commission for Manpower Policy, 1975, p. 2).

Thus, before manpower needs can be projected, the feasibility of developing specific energy sources must be examined. And in many instances, that feasibility will be determined by governmental actions which are based on specific policies.

Generally speaking then, whether a specific energy source is developed rests on four considerations: (1) the resource must be present, (2) the development of the resource must be economically feasible, i.e., a return on capital investment can be realized, (3) environmental and other Federal and state regulations will not make development of the resource too costly, and (4) a skilled labor pool is available. These four considerations are highly interdependent.

In planning the present study, it was believed that what policies those involved in the developing energy industries perceived as existing or expected to emerge would affect their decisions about how to invest. And those decisions will determine manpower needs during the next ten years. Two questions were asked during the interview in order to learn what perceptions industry executives and researchers held. The questions were as follows: (1) In New Mexico or Arizona, what energy policies related to manpower needs exist now? (2) With developing sources of energy, do you foresee new energy policies emerging? Lists of responses to these questions are provided in Appendix D.

Implications of the responses to the questions concerning policy are discussed in the following pages. Particularly, in the case of nuclear energy, helpful information is available in the literature and will be included here. The discussion is presented by energy source and covers the responses elicited to both of the questions mentioned above.

Coal Gasification

Existing Policies. Existing policies that affect the status of coal gasification are represented in strip mining laws and the Environmental Protection Agency's (EPA) operational regulations concerning pollution of water and air. The former laws stipulate restoration of used (stripped) land. Because this adds extra expense to the cost of mining, these laws are not favored by the mining companies. By the same token, the EPA's regulations are not wholeheartedly welcomed by these

companies. Moreover, the EPA's regulations, according to the same respondent, "slow down development."

Suggested and Emerging Policies. Coal gasification is a capital intensive source of energy. "Estimates provided by EPNG (El Paso Natural Gas) and WESCO (Western Company) with their applications for construction permits indicate a construction cost ranging from $380 million to $450 million in 1972 dollars for each plant, not including mining" (Development Research Associates & Gruen Associates, 1974, p. 1-3). In 1977, according to Mr. Edward Walsh of El Paso Natural Gas, the cost for constructing one plant has risen to about $1.2 billion. The money needed to construct a coal gasification plant is costly and, without Federal backing, difficult to obtain.

It was also pointed out that before a company can commit itself to this kind of capital investment, it needs to have definite indications about environmental policies. At present, environmental regulations are changed frequently and are usually made retroactive. If a company is extended to its limit in building a new plant it might be unable to satisfy further changes in regulations which required installation of new, expensive equipment for which expenditures were not planned. Some further discussion of the effect of environmental regulations on the development of energy sources can be found in the section dealing with nuclear power generation.

Two respondents foresaw an increase in tax rate on the removal of uranium and coal. Such tax policies might have a negative effect on the capital investment in coal and uranium. Finally, the development of a policy related to eminent domain allowing slurry pipe lines to cross railroad right of ways could affect how coal would be used. This matter is currently a matter of discussion in Congress.

Geothermal

Existing Policies. The existing laws related to geothermal resources in New Mexico and Arizona deal with land leases and environmental protection. These laws regulate geothermal resources exploration and development. The environmental protection laws make it necessary for companies engaged in developing geothermal energy to keep in mind that the protection of the environment is as important as their search for energy. However, respondents expressed their concern about the way these laws have been implemented. The red tape associated with the application of these regulations bothers them. Specifically mentioned was the exhaustive hearings by the Environmental Protection Agency (EPA).

In Arizona, the moratorium imposed on geothermal land leases has forced geothermal exploration and development to a virtual standstill. The moratorium was imposed to give state officials opportunity to decide whether the resource falls into the category of mineral or water and thus to determine which regulations will apply. As a result, very few organizations engaged in geothermal activities were identified. However, a geothermal energy conference held in Phoenix in November drew support from many Arizona officials. Governor Raul Castro spoke at the meeting and stated his interest in and support of the development of geothermal energy.

Federal loans for geothermal resource exploration and development are available through ERDA. However, as one researcher respondent put it, "There is no consistent policy supporting energy exploration research. Thus, there is no incentive for students to enter these fields of study." This statement was uttered in the context of discussing the presence or absence of geothermal energy policies in Arizona.

Petroleum companies were described as obstacles to the development of geothermal energy. In the same line, one respondent mentioned that utility companies did not show interest in geothermal energy. This too reflects the idea that utility companies must encourage the development of emerging energy sources. Utility companies, being profit-making organizations, invest their capital in projects which they deem economically feasible and profitable to them. A responsible person in a geothermal corporation indicated that his company will make agreements with local utility companies when production stage is attained. This probably implies that utility companies are ready to participate in low-risk projects.

The formation of the New Mexico Energy Institute with three branches at New Mexico universities was perceived by one respondent as promising. The respondent specifically mentioned the New Mexico Energy Research and Development Institute at New Mexico State University because geothermal resources investigation lies within its domain. The institute also deals with solar energy, wind power, and waste conversion. The other branches are as follows: the New Mexico Energy Institute at the University of New Mexico is responsible for research in conservation, the nuclear fuel cycle, socio-economic considerations and synfuel. The New Mexico Energy Institute at New Mexico Institute of Mines and Technology is responsible for research in coal, gas, oil and tertiary recovery (Office of Director, NMEI, NMSU, undated).

Suggested and Emerging Policies. As is the case with coal gasification, large capital investments are required in geothermal exploration, drilling, and development. According to one senior geologist respondent, the cost of building a 110 megawatt geothermal energy plant runs in the neighborhood of $25 million. In addition, it takes 10 years to produce and deliver power to consumers. Government support of such projects would induce development. Types of support suggested were tax relief, depletion allowances, and grants and subsidies. Moreover, public policies that stress efficiency and effectiveness in administrative procedure need to evolve. The large number of hearings conducted by the Environmental Protection Agency (EPA) was resented by one respondent. With the present rate of inflation, delays in construction caused by environmental hearings can result in dramatic increases in the cost of wages and materials.

Nuclear

Energy policies. Government policies which affect the development of nuclear energy will, in all likelihood, affect the development of other alternative energy sources as well. For example, if the Federal government, as President Carter proposes ("President's Energy Program," April 20, 1977, p. 25; "Remarks of the President," April 20, 1977, p. 8), could implement policies so that the licensing, design, and construction of nuclear plants could be reduced from 10 to 3 years, the nuclear industry would enjoy a clear-cut cost advantage. As a result, much of the pressure to develop other sources of energy might be alleviated. And without that pressure, Federal sources of funding to assist in the research and development of alternative energy sources might either slow to a trickle or dry up completely. Regardless of these considerations, it seems apparent that during the next 10 years, coal and nuclear fuel will be the most common means of firing new electrical generating plants. It also seems apparent that how rapidly nuclear energy is developed and how much emphasis is placed on the development of nuclear energy will affect how rapidly the alternative energy sources are developed. And while the nuclear power industry is not new to the United States, it is new to New Mexico and Arizona.

Three nuclear power plants are now being planned and built in Arizona. At present, none are in the planning stages for New Mexico. But since both the Los Alamos Scientific Laboratory and Sandia Laboratories have nuclear research facilities and since research at the two facilities is not restricted solely to military activities, manpower needs in New Mexico will be affected by developments in the nuclear power industry.

A number of national policies affect the development of nuclear power generating facilities. Because much has been written about these nuclear policies, the literature must be taken into consideration. Both existing and emerging policies are discussed at length; therefore, a brief review of the literature has been included here.

Until the present, the United States' nuclear power plan has centered around the concept of a nuclear fuel cycle whereby nuclear wastes would be reprocessed and recycled (Metz, 1977, p. 284). However, at present the nuclear fuel cycle has not been "closed." There is no plant presently licensed and operating which recyles wastes from nuclear power plants (Bebbington, 1976). Furthermore, a number of environmental groups have expressed concern about the disposal of nuclear wastes; for example, the Natural Resources Defense Council, an environmental law group, "continues to press for a moratorium or slow down on expansion of nuclear power until the NRC formally determines that radioactive wastes will in fact be disposed of safely" (L. J. Carter, 1977, p. 661).

It has been asserted that "this country's nuclear enterprise will be in serious trouble unless the Energy Research and Development Administration (ERDA) demonstrates, and demonstrates fairly soon, that radioactive wastes can be permanently isolated from the human environment" (L. J. Carter, 1977, p. 661). Others argue that the problem of nuclear waste disposal is artificial, created because the U.S. Atomic Energy Commission provided inadequate funding and that now proper funding is bringing forth satisfactory solutions (Rose, Walsh, Leskovjan, 1976, p. 293).

Disposal of low-level wastes (wastes containing no significant amount of plutonium and having relatively short radioactive lifetimes) has remained a matter to be dealt with by the private sector. Such wastes are disposed of at sites licensed by the Nuclear Regulatory Commission (NRC). However, the Federal government is involved in disposal of high-level radioactive wastes. The possibility of developing a nuclear waste disposal site near Carlsbad, New Mexico, is being investigated by Sandia Laboratories. According to the project manager, the Carlsbad project is being developed mainly as a demonstration site for disposal of nuclear wastes produced by the defense industry. However, the specifications for the project require that the site be made compatible for disposal of high-level wastes from privately operated nuclear power plants. Thus development of the nuclear power industry and of policies favoring waste disposal could have an impact on manpower needs in the Carlsbad area, if the state allows the site to be developed.

There are other policy matters now being discussed which will affect the future of the nuclear power industry. The government is concerned about the proliferation of nuclear weapons built using the plutonium produced from nuclear wastes. To avoid proliferation, President Carter has announced his intention to prohibit production of plutonium from recycling of nuclear wastes ("President's Energy Program," April 20, 1977, p. 24). Because the breeder reactors produce plutonium, U.S. projects to develop the fast breeder reactor may not be funded. If breeder reactors are not developed, it is predicted that there is only enough fuel to last the lifetime of all plants likely to be installed by 1990 (Boyer, 1976, p. 5). Plant lifetime is estimated to be between 20 and 40 years.

Luther J. Carter (1977) is also pessimistic about the availability of nuclear fuel. He states that long-term use of nuclear fuel as a major energy resource depends upon development of the breeder reactor, which in turn depends upon fuel reprocessing and the recycling of plutonium. It must be pointed out that use of the breeder reactor would result in a great accumulation of high-level radioactive waste which must then be disposed of. Thus, President Carter's policy prohibiting the production of plutonium and the recycling of wastes increases the likelihood that the Carlsbad project might become tied to the nuclear power industry. If the spent fuel is not recycled there will be an even greater demand for waste storage. At present, New Mexico is under a one-year moratorium which prohibits "the disposal within New Mexico of radioactive material generated outside" New Mexico until March 31, 1978 (Senate Bill 55). Sandia personnel say this moratorium has no affect on the Carlsbad project.

The abundant supplies of coal in northwestern New Mexico also affect the probability that more nuclear power plants will be sited in Arizona and New Mexico. In this specific two-state area, the cost of electricity obtained from coal-fired generating plants appears to be about the same as that obtained from nuclear plants, but this is a regional phenomena. Costs of nuclear generated power in the eastern United States are projected to remain lower than costs for fossil-generated power.

If one compares the projected prices of electricity from nuclear- and coal-fired plants, nuclear has generally been shown to produce electricity at the lowest overall cost. For example, Table 2 shows the average total costs of electricity in 1975:

Table 2

Cost of Electricity, 1975

Nuclear	Coal	Oil
1.2¢/kwhr. (ore, enrichment, reprocessing)	1.7¢/kwhr. (with scrubbers)	3.3¢/kwhr.

Source: V. S. Boyer, 1976

Without reprocessing and recovery, the nuclear fuel cost is estimated to be about 1 mill per kilowatt hour higher. While the price of nuclear fuel might rise by 14 percent without recycling, the total nuclear plant cost would increase less than 3 percent (Boyer, 1976). These projected prices are consistent throughout the literature.

However, projections for 1985, broken down by region, show a different story. Reichle, in December 1976, made the projections shown in Tables 3 and 4 for plants generating 2,400 megawatt electric (2 nuclear stations or 3 coal-fired stations).

At present, a much larger capital investment is needed for building a nuclear plant: capital which it is very difficult for the utilities to obtain and which utilities hope new Federal policies will help produce. Delays caused by hearings about environmental matters and licensing can increase capital costs dramatically because while construction is delayed, costs for loans, material, equipment, and labor

Table 3

Cost Projections: 1985

Nuclear

	Eastern	Midwestern
Total Cost	51 mills/kwhr.	50 mills/kwhr.
Capital Investment	$1,270/kwe	$1,235/kwe
Fuel		
Recycled	$ 97.16/kwe	
Without Recycling	107.72/kwe	

Source: Reichle, 1976

Table 4

Cost Projections: 1985

Coal

	Eastern	Midwestern (Without SO_2 Removal)
Total Cost	65 mills/kwhr.	48 mills/kwhr.
Capital Investment	$1,150/kwe	$870/kwe ($1,170/kwe with SO_2 Removal)
Fuel	$34/ton	$15/ton

Source: Reichle, 1976

continue to increase (Rossi, Ritchings, 1976). "The high capital cost of nuclear plants tends to favor decisons for coal burning ones, despite the certain long-term penalty" (Rose, Walsh, Leskovjan, 1976, p. 292). If these delays could be avoided as President Carter proposes, then the initial capital investment would be reduced considerably.

The long-term penalty for coal refers to the higher operating costs necessitated by the higher costs of fuel (a highly unpredictable matter because of the unsettled nature of Federal policies regarding the nuclear fuel cycle) and because a greater number of people are needed to operate a coal-fired generating station than are needed to operate a nuclear power plant. For example, the Navajo Plant, a coal-fired plant, employs 571 operating and maintenance personnel and generates 2,250 megawatts electric. The projections for the Palo Verde Station, a nuclear plant, estimate 300 operating and maintenance personnel to generate 3,810 megawatts electric.

The amount of lead time now required to build a nuclear generating plant has increased from six years in 1969 to ten years in 1976, because of present Federal and state regulations and licensing procedures. It is possible to install a coal-fired plant in six years (from authorization to operation) (Rossi and Ritchings, 1976). The number of environmental requirements have increased for both coal-fired and nuclear plants. Both must satisfy the Clean Air Act Amendment of 1970 and the Water Pollution Control Act Amendment of 1972. In addition, regulations for nuclear plants are still being revised. Rossi and Ritchings (1976) state that approximately "110 regulatory guides have been issued to supplement or interpret or define specific approved methods of fulfilling

the AEC (NRC) regulations". These guides are still being issued at the rate of two or three per month. In the present survey, utility executives mentioned the problems of complying with Federal regulations frequently. It was stated that so much capital was involved that utilities were reluctant to make the decision to build, for a change in regulation could necessitate drastic changes in the type of equipment needed to comply with the new regulation and force even greater capital costs.

Again, new policies could alter the picture. First, if SO_2 removal is required on all western coal as President Carter has recommended, the cost of producing electricity from western coal will increase substantially. Second, reducing the time required for licensing would reduce capital costs of nuclear plants. Rose, Walsh, and Leskovjan (1976) estimated that if the time between planning and operation could be reduced by two years, much of the nuclear cost disadvantages could be eliminated. Thus the balance could easily swing back to nuclear as being less expensive in the Arizona-New Mexico region.

Besides the policies pertaining to the development of nuclear and coal-fired generating plants discussed above, which direct attention to where employment will be available, other Federal policies were mentioned as needed by the utilities during interviews.

The utility companies point out that they will continue to be expected to provide electricity; and they will be called upon, even by homes using alternate energy sources, to provide electricity on cloudy or windless days. The utilities must have their rates approved by Federal and state regulatory commissions, and if they are to serve the needs of their customers, their rates must be set to protect their investment if the electricity is to be available at all times. The utilities want the rates to include an assured reimbursement for the cost of service. Furthermore, the capital investments made by utility companies are large. To obtain the needed capital, the utilities say they need Federal support. It was suggested that perhaps the Federal government could change present pricing policies to allow companies to make loans on future income or that the government could guarantee loans made to pay for capital investments.

Manpower Policies. A number of policies directly affecting manpower needs and the character of those needs emerged from the interviews and from the search of the literature. The affirmative action programs, according to interviewees, have affected the type of people companies recruit. Companies have reevaluated requirements for college

degrees and now emphasize basic skills, i.e., reading and writing. For example, the Salt River Project (SRP) employs technicians at four levels. All technicians must enter at Level 1: the company requires that a Level 1 technician have college English and mathematics. Those with more initial training may work up to higher levels more quickly as they satisfy the requirement for work experience. There are trade-offs between work experience and college study to a certain extent, for example, Salt River Project sets 40 college credit hours as equal to 1 unit while 1 year of work experience is valued at 4 units for promotion purposes. SRP employs 12 persons to develop in-house training programs in various areas, such as electrical theory, machine work, welding, and laser technology. Technicians are thus offered opportunities for in-house training which will increase their chances for promotion.

The utility companies promote from within whenever possible. This policy reinforces the policy requiring basic entry level skills. F. C. Rittenhouse (1976) observed that people graduating from schools where they have been trained in such needed skills as knowledge of mechanics, electricity, or welding technology still must go through a beginners orientation period. Thus a person who enters with trained skills might not be placed in a skilled position for months or years.

In the same article, Rittenhouse points out that the Equal Employment Opportunity Commission (EEOC) requirements have affected training procedures as well as employee selection procedures. The power companies are providing more formal training to satisfy Federal agencies such as the EEOC, the Nuclear Regulatory Commission (NRC), and the Occupational Safety and Health Administration (OSHA).

Yet, during the interviews, utility officials stated that requirements have resulted in a demand for greater specialization. Those seeking jobs with utility companies and those hoping for promotions find it necessary to specialize. Companies describe requirements for specific jobs in great detail to avoid legal entanglements; furthermore, the most qualified may be those with greater specialization, even for entry-level positions, although a college degree would not be required.

Solar

Existing Policies. Both Arizona and New Mexico have enacted legislation to encourage the development and use of solar energy. In the survey conducted for this study, 12 respondents mentioned the existence of laws concerning tax

incentives for solar energy development in Arizona and New Mexico. However, six respondents thought the existing laws were inadequate. It was maintained by some that the present tax incentives are not sufficient to induce the middle income home owner to consider purchasing solar equipment. Also, it was pointed out by a member of the research project's advisory board that the addition of solar equipment in New Mexico will increase the property tax evaluation of the home -- a negative tax inducement. Arizona specifically exempts solar equipment from taxation. Of the 46 usable interviews obtained in contacting 50 solar energy businesses, 12 mentioned tax incentives as an important government policy. Both private businesses and public agencies indicated unwillingness to venture into a new and untried field without government support, and tax incentives were viewed as an important supportive policy which government could provide.

One person pointed out that tax relief was not provided to those who work in energy-producing units. Perhaps tax relief should not be exclusively limited to utilizers of solar energy but should include those who work in producing materials for the solar energy system.

Other incentives were mentioned which encourage capital investment in new ventures such as solar energy development. Some savings and loan companies will lend money for solar energy development provided that borrowers guarantee to sell 70 percent of their products. This stipulation is considered a constraint, but at the same time forces those who seek loans to work harder.

Federal grants which are administered by the Energy Research and Development Administration (ERDA) are devices through which the adoption of emerging energy sources can be encouraged. For example, a respondent indicated that Federal grants were being used in teaching secondary school students about the practical applications of solar energy in everyday life. The respondent mentioned his participation in such a program. Students, as future leaders and present consumers, can act as vehicles in the process of information dissemination.

Resentment could be detected from such statements as, "More money in the form of depletion allowances or other types of government subsidy is granted to the producers of the conventional energy sources." This comment probably refers to natural gas. Here again, the role of government money was stressed as important in the expansion of the energy industry.

One respondent considered the absence of guidelines on depreciating solar equipment and the special treatment given to some conventional fuels, such as natural gas, as discriminating against solar energy. These policies, he believes, act as barriers against the effective utilization of solar energy. Another respondent mentioned that Pima County, Arizona, has been issuing various codes which give support to the wide use of alternative energy sources. Zoning laws were mentioned, generally, as a problem.

Utility companies play important roles in the economies of New Mexico and Arizona, and they were perceived by two respondents as barriers to the wide use of solar energy. The respondents depicted utility companies as barriers because of their total reliance on conventional sources of energy. Conflicts of interests between the rising new small business ventures in the solar energy industry and the major utility companies may arise because of competition for Federal dollars. Also, widespread use of solar equipment in private homes could play havoc with utility rate structures.

Realizing the urgency of accelerating programs for the development of emerging energy sources and recognizing the influence of the utility companies and university research and development (R&D) centers upon development, the Federal government has invested its money in their activities. These organizations and centers possess work facilities that can enable them to fulfill the requirements demanded for the receipt of Federal grants. But small companies have, by and large, had to finance their own development activities. Consequently, some believe they are forced into competition with the Federal government if they wish to continue working in the development of solar energy.

The states of Arizona and New Mexico have created administrative machineries to promote the cause of emerging energy sources. The Arizona Solar Energy Commission, since its inception in 1975, has made efforts to orient the Arizona public to the practical utilization of solar energy. A solar marketing firm and a private research and development firm estimated that perhaps one-half of their financial sources were expended on information dissemination.

In New Mexico this task has been handled by both the state and by volunteer citizens. The New Mexico legislature passed the "Solar Energy Development Act" in 1975, and interested New Mexico citizens formed a private solar energy association. The aims of both are to popularize and promote the practical applications of solar energy. These activities show that the populations of New Mexico and Arizona place a good deal of confidence in solar energy as an alternative energy source.

Two respondents mentioned the existence of minimum wage laws as affecting manpower usage in the emerging energy areas. Their responses indicated that, in their opinion, minimum wages make energy development capital intensive.

Suggested and Emerging Policies. Laws that regulate access to the sun and construction of houses on the basis of a system that may minimize conflicts among users of solar energy are essential. The probability that some such laws may be enacted looks high.

Respondents tended to believe that government fiscal support was necessary for the full success of solar energy programs. This was expressed in their demand for government subsidies and a 100 percent deduction on the cost of installation on state income tax for solar energy systems, Federal tax reduction on energy saving devices, investment tax credits, and Federal monetary inducements to purchasers of solar heated homes and pools. Likewise, a need for an investment tax credit, accelerated depreciation credit, and the removal of the subsidy provided on conventional fuels was indicated. A sum of 13.5 percent of the respondents indicated that any new emerging policy should emphasize conservation and utilization of solar energy. It seems President Carter was responding to similar demands when he said, "Our program will emphasize conservation...[and] research on solar energy" (1977, p. 260).

Respondents also stressed that the Federal government should provide insured, low interest loans to solar energy developers. They thought that banks should extend more credit for solar energy systems installation and, generally, for innovative energy projects.

All these demands from and upon the Federal government will eventually enhance its role in formulating public policies. Although three respondents would not approve government intervention, they did not object to receiving grants-in-aid.

Planning for the development of solar energy was mentioned in two responses. The respondents seemed to feel that through planning time could be saved and disorganized efforts could be coordinated. This ultimately might prepare the way for the development of sound energy policies.

Red tape is inherent to large and complex bureaucracies. Because of this, one respondent was unable to envision the emergence of favorable energy policies in the forseeable future. On the other hand, two respondents indicated faith

in the new (Carter) administration. According to the NBC newscast of March 29, 1977, President Carter requested that Congress help him reorganize the Federal government's bureaucracy. Such a reorganization might have far-reaching consequences in energy affairs. Uniting the efforts of the various Federal agencies will eventually assist in developing predictable policies.

Seven respondents proposed standardization of solar energy system work requirements. Issuing of licenses on the basis of well-defined requirements, protection of patent and establishment of standards for solar equipment were emphasized. The establishment of guidelines would impel prospective as well as existing employees in the solar energy industry to improve their skills and competencies.

To meet the expected demand for trained workers in solar energy, in the opinion of one respondent, relevant educational policies should evolve. These policies must emphasize training needs in plumbing, sheet metal work, installation, and sizing of systems. One ex-university professor respondent proposed a study program composed of a course on "retrofit" for current plumbers, a solar engineering course worth three credit hours for mechanical engineers, and general training in solar energy systems for employees already working in heat and refrigeration.

Educating the general public in the application of solar energy systems was considered to be vital by 12 respondents. They thought that clear explanations in lay terms coupled with demonstrations might help in the dissemination of information on emerging energy sources. They recommended that solar heated homes be built to familiarize the public with the state of the art. The New Mexico Energy Institute, in cooperation with private donors, built a solar-heated house for research purposes. A Department of Agriculture building on the campus of New Mexico State University is heated by solar energy. The buildings serve to demonstrate the practical applications of solar energy in office and home heating. A great number of visitors do tour these buildings.

Dissemination of information on solar energy, reported one respondent, requires maximum use of the mass media. Three respondents suggested that establishment of information dissemination centers may assist in bringing pertinent materials within reach of the ordinary citizen.

Waste Products

The feasibility of using the methane from animal and human wastes and from garbage has been examined for potential use as an energy source. Because waste products must be disposed of in any event, the possibility of using these products as a source of energy seems extremely attractive. Respondents estimated that as much as 15 percent of the energy needs of the United States could be satisfied by proper management and use of waste products. However, current studies indicate that the cost of using waste products to produce energy is prohibitive.

As the cost of other fuels go up, using methane derived from waste as an energy source will prove more cost effective. Respondents listed the following as major problems associated with the use of waste-derived methane: (1) the methane is only 60 percent as efficient as natural gas; (2) the cost of processing the methane to remove impurities, especially CO_2, is high; and (3) the untreated methane is extremely corrosive, causing problems in any kind of delivery system, unless the methane is processed.

Alternative uses of waste products are being examined and may prove more attractive. For example, nuclear wastes can be used to sterilize human and animal wastes, making them safe for use as animal feed or as fertilizer. This development could serve to stimulate interest in nuclear energy, as attractive uses of the nuclear wastes are found. At the same time, the use of animal wastes as a source of energy might become less attractive.

The best use for garbage from large municipalities is, according to several respondents, to burn the solid wastes as fuel for generating electricity. In general, the overriding policy concerning the use of waste products is cost effectiveness. And at present, other energy sources remain less expensive.

Wind

Wind as an energy source has been used for centuries, and windmill technology is being revitalized. The use of wind to generate electricity is being investigated presently. Wind speeds have been mapped for New Mexico (Barnett, 1977; Reed, 1977). According to officials at the Arizona Office of Planning and Development, there is not sufficient wind in Arizona to consider wind as a viable energy source in that state. More research is being done in New Mexico, but the work is largely experimental.

National Manpower Policies

Respondents mentioned frequently that certain Federal regulations affected plans to develop a particular industry and to employ workers. The affirmative action program was mentioned as a case in point. It was stated that because of affirmative action, schools should concentrate on providing basic skills, and for some employers basic skills meant the ability to read and write. A college degree is no longer needed, and dropping this requirement has affected employment patterns. At the same time, some respondents maintained that affirmative action has forced greater specialization to avoid law suits. A number of respondents with small business operations stated that they intended to keep their businesses small because of the reporting requirements associated with the affirmative action regulations, should the growth of their business entail employing a large number of people. In general, government red tape was mentioned frequently as the reason small businessmen would not participate in Federal programs. Other agencies mentioned specifically were the Occupational Safety and Health Administration and the Department of Housing and Urban Development.

Conclusions

Certain generalizations can be made on the basis of responses to questions about state and Federal energy policies. Respondents were positive about the existence of the Arizona Solar Energy Commission and the New Mexico Energy Research and Development Institute. The existence of these entities for many represented support, on the part of the state government. While, generally, respondents could see the value of state support of research and development, many believed equal support should be extended to businesses active in developing energy sources. Of paramount concern was financial support.

Environmental considerations were mentioned by many respondents. Some stated that Federal environmental regulations inhibited development of energy projects. These respondents were concerned about laws controlling strip mining and about laws regulating emissions into air and water. With regard to the latter, the problem was said to be one of changes in standards and uncertainty about standards. Others stressed the need for conservation of our present energy sources as an important environmental consideration.

A number of respondents expressed fear that special interest groups and large utility companies were blocking

the development of alternative energy sources, especially the development of geothermal and solar energy. On the other hand, representatives of utility firms stated their support of developing alternative energy sources. But these spokesmen stressed that the utilities needed protection for the large investments they were making.

Several respondents suggested that the effect of new energy policies might be to create conflicts between energy producing states and energy consuming states. For example, the states of New Mexico, Arizona, and Wyoming may wish to tax energy production and exportation. The Federal government may intervene to prevent these taxes. In the case of an underdeveloped state such as New Mexico, which pays high rates on gas produced in the state, Federal policies favoring energy importers can have serious consequences on energy exporting states. The high rates on energy can discourage the development of other industries within the energy exporting state (Energy Resource Board, 1977).

Finally, the most common reaction by respondents to questions about energy policies was that there is no energy policy. Many stated that until the Federal government provides some direction, i.e., enacts a national energy policy, very little will be done to develop new energy sources. Further, respondents suggested that perhaps if the United States suffered a national disaster with many deaths resulting from an energy shortage something would be done. On this one point all responses were in agreement, those interviewed want a national energy policy.

Chapter 3

Projected Manpower Needs

A major objective of the study was to identify possible manpower needs in the emerging energy fields and to identify the levels of training needed for each identifiable occupation. To accomplish these two objectives, the interviewers were to complete, with the help of the respondents, a table wherein specific information was to be supplied by the respondent.

The table (see Appendix B, Question 4) contained eight columns. Column 1 asked for job titles. The job title and definition used might correspond to a title and definition appearing in the Dictionary of Occupational Titles, or it might not, since emerging occupations were under discussion. The interviewer wrote down what the respondent considered a reasonable title; in some cases, the respondent specified a job description rather than a job title. Column 2 asked for the educational level appropriate for the job title suggested. Sometimes the prerequisite for the job might be work experience or the mastery of such basic skills as reading, writing, and arithmetic. Column 4 was intended to discover whether retraining would be required. Column 5 inquired about the duration of the employment. This column and columns 6 and 7 were intended to ascertain, in a rough way, the economic remunerations and the location of the job being sought. Finally, the respondents were asked to estimate, for their business operation, the number of employees needed by job title for the next 5 to 10 years in Column 8.

The table was difficult to complete, partly because the large research and development agencies could not make projections pertinent to the question posed. In the research laboratories, highly trained personnel are employed. But continuation of any work depends on contracts, and what kind of work is done depends on what kinds of contracts are obtained. This makes projections about future employment needs unreliable. Also, the very small businesses said they would remain small, again making projections difficult. In the following pages, the estimations provided by employers are presented and discussed by energy source.

Coal Gasification

The development of the coal gasification industry, as was indicated in Chapter 2, depends on what the Federal energy policy will be. If the coal gasification plan proposed by El Paso Natural Gas receives Federal support, tremendous employment opportunities will emerge in New Mexico. The growth of a new town will be witnessed in Northwestern New Mexico. It is estimated that this town will grow dramatically from no population to 32,000 in ten years (Development Research Associates and Gruen Associates, 1974, p. E-2).

The estimated manpower required for the construction and operation of a typical 250 million cubic feet per day coal gasification plant appears in Tables 5 and 6. The tables indicate that, except in engineering, a four-year college education is not essential. More emphasis is placed on acquiring skilled technicians. Pipefitters and pipefitter/welders account for one-third (32.5 percent) of the required labor force.

For construction, the second and third in rank according to number of employees required by each category are laborer (14.3 percent) and electrician (10.1 percent). Operating engineers, highly trained equipment operators, constitute 8.3 percent of all manpower. Surveys show a need for training in pipefitting, welding, equipment operation, and electricity in particular. Laborers would be trained in-house.

The labor force of the coal gasification plant will eventually be reduced to one-fifth the number required at the time of plant construction. Almost one-half (47.8 percent) of the labor force for operation will consist of process operators. The main work of the process operator is to regulate and monitor the coal gasification process. According to Mr. Walsh of the El Paso Natural Gas Company, these employees will acquire knowledge of the work by taking part in the operation. On-the-job training will be provided by the company.

About one-third (29.1 percent) of the operating work force will be made up of plant mechanics. The categories of process operators and plant mechanics constitute 76.9 percent of the total operation work force. This suggests that the project will be machine-dominated at the operation stage. Specialized skills will be a prerequisite to joining the company's labor force.

Table 5

Estimated Technical and Skilled Manpower
for a Typical 250 Million
Cubic Feet Per Day Coal
Gasification Plant

Construction

Type Worker	New Mexico[1]
Carpenter	192
Boilermaker	113
Boilermaker/Welder	85
Millwright	130
Millwright/Welder	30
Ironworker	240
Operating Engineer	300
Pipefitter	730
Pipefitter/Welder	440
Teamster	80
Laborer	515
Electrician	363
Sheet Metal Worker	30
Bricklayer	20
Cement Mason	154
Painter	61
Asbestos Worker	121
TOTAL	3,604

[1]Peak requirement for each skill.
Peaks do not necessarily coincide.

Source: El Paso Natural Gas Company, 1976.

Table 6

Estimated Technical and Skilled Manpower
for a Typical 250 Million
Cubic Feet Per Day Coal
Gasification Plant

Operation

Type Worker	New Mexico
Engineers	30
Chemists	5
Draftsmen	3
Lab Technicians	14
Safety Technicians	10
Process Operators	350
Plant Mechanics	213
Machinists	25
Welders	34
Painters	5
Electricians	17
Communication Technicians	5
Corrosion Technicians	3
Instrument Technicians	15
Equipment Operators	3
TOTAL	732

Source: El Paso Natural Gas Company, 1976.

By comparing Table 5 with Table 6, it can be seen that three job titles will be transferable from the construction phase to the operation phase. The job titles are welder, painter, and electrician. The number of employees in each job title decreases.

Although the construction labor force will be reduced by four-fifths when operation begins, the construction period for each plant will last three years, providing work opportunity for a large number of employees. Seventeen job titles at the construction and 15 job titles at the operation stage will be needed for each coal gasification plant.

Geothermal

Table 7 shows the forecasted job titles and the anticipated number of employees for the next 5 to 10 years in geothermal energy. This projection was based on a 50 percent sample of New Mexico businesses and on 100 percent of Arizona businesses. Because of the existing state moratorium on land leases, very few organizations and individuals working in geothermal energy were identified in Arizona; thus no sampling was necessary.

A close examination of the job titles in Table 7 reveals that transfer of technology from the existing petroleum occupations is possible. The only new job title looks to be instrumentation technician, for which about 10 employees are forecast to be needed.

Unless a sudden and unexpected change takes place in the field of geothermal energy, it is probably safe to conclude from the data in Table 7 that few employment opportunities will emerge for the next 5 to 10 years in New Mexico and Arizona. The implication of this for educational training is obvious. There will be no need for developing new courses in the geothermal energy industry. With some modification to accomodate specific work requirements, the existing training courses will suffice.

Table 7

Job Titles and Projected Number of Employees

Geothermal

Job Title	Competencies	New Mexico Sample	New Mexico Population	Arizona Population	Total
Geologist	petroleum geologist	7	14		14
Drilling Engineer	experience in petroleum	2	4		4
Reservoir Engineer		1	2		2
Superintendent	engineer	1	2		2
Production Foreman		2	4		4
Instrumentation Technician				10	10
Roughneck		6	12	10	22
Drilling Crew		15	30		30
Drilling Superintendent	engineer	2	4	—	4
		36	72	20	92

Nuclear

During the next ten years, coal and nuclear fuel will become the most common means of firing new electrical generating plants. A number of variables will affect how many people can hope to obtain employment in the nuclear power industry in Arizona and New Mexico. Because of hiring and promotion policies, people staffing the nuclear generating stations will be those with experience in power generation. Both Arizona Public Service and the Salt River Project suggested that the Palo Verde Nuclear Station will attract people from the Four Corners area. Thus when the Palo Verde Station begins operation, entry into the power industry may be through positions in the Four Corners area, working in the coal-fired generating plants. For this reason, Appendix E provides manning information for two coal-fired generating plants.

Construction on the Palo Verde Nuclear Station has begun. Bechtel Power Corporation is the contractor for construction. Construction of the station "is placing a demand on skilled labor from the construction trades in the Phoenix area" (McEntee, March 15, 1977). The manpower loading will peak during the period from 1979 to 1981 and then will taper off through 1986, when the third unit is scheduled for completion. Unit one, the first plant, is scheduled to begin commercial operation in 1982. Table 8 represents Bechtel's projections of manpower needs for the next 5 to 10 years for the Palo Verde Station.

Earlier studies had indicated that shortages might occur in specific trades. The Project Independence report had stated that the greatest shortfall nationwide would be for pipe/steam fitters (1974, p. 147). Gallagher and Teather projected that the greatest shortfalls of skilled craftsmen would be for electricians and boilermakers (1976, pp. 3-3,4). Of the manual construction labor force, 50.9 percent of the skills needed are projected to be in these three crafts. Other craftsmen in demand during construction will be carpenters (12.5 percent of the manual work force during construction) and ironworkers (9.7 percent). On the project, there will be 573 positions requiring college degrees; there will be 2,590 craftsmen. In other words, for 18.1 percent of the work force employed during plant construction will college degrees be required. A breakdown by job title, level of training, and competencies required is provided in Table 8.

In an earlier study by Blair and Barker (1975), the demand and supply of nuclear-related technicians was projected for twelve western states, including New Mexico

Table 8

Construction of the Palo Verde Nuclear Station

Competencies of Employees
(Next 5 to 10 Years)

Job Title	Level of Training	Competencies (Skills Emphasized)	Need for Retraining	Length of Employment	Salary	Location	Number of Employees
			NON-MANUAL				
Engineering	B.S. or higher	Construction exp. EE, CE, ME	Yes-by Bechtel	Permanent	$1,000-up	Phoenix area	192
Cost/ Schedule	B.S. or higher	Construction exp. EE, CE, ME	Yes-by Bechtel	Permanent	$1,000-up	Phoenix area	20
Procurement	B.A. or equiv.	Purchasing, contracts, traffic	Some-by Bechtel	Permanent	$800-up	Phoenix area	36
Quality Control	B.A. or equiv.	Specification, inspection procedures, testing	Some-by Bechtel	Permanent	$800-up	Phoenix area	50
Subcontract Admin.	B.A. or equiv.	Contracts, legal specs., accounting	Some-by Bechtel	Permanet	$800-up	Phoenix area	13
Supervision	B.S. or equiv.	Construction, labor relations	Yes-by Bechtel	Permanent	$1,200-up	Phoenix area	75
First Aid Safety, Fire Protection	B.A. or equiv.	Specialty	None specific	Permanent	$800-up	Phoenix area	15

Table 8 (continued)

Job Title	Level of Training	Competencies (Skills Emphasized)	Need for Retraining	Length of Employment	Salary	Location	Number of Employees
Computer Operations	B.S. or higher	Operating, Programming	None specific	Permanent	$1,000-up	Phoenix area	8
Personnel	B.A. or equiv.	Employee relations	None specific	Permanent	$800-up	Phoenix area	4
Admin. & Services	B.A. or equiv.	General administrative	None	Permanent	$800-up	Phoenix area	50
Non-professional Support	A.A. or H.S.	Technical support clerical	None	Job Duration	$600-up	Phoenix area	110
						TOTAL	573
			MANUAL				
Operating Engineers	Apprentice	Equipment operators	None	As required Union by schedule scale		Phoenix area	135
Cement Masons	Apprentice	Cement work	None	As required Union by schedule scale		Phoenix area	30
Teamsters	Apprentice	Transportation warehouse	None	As required Union by schedule scale		Phoenix area	100
Painters	Apprentice	Surface prep., painting	None	As required Union by schedule scale		Phoenix area	35
Ironworkers	Apprentice	Structural steel fabrication	None	As required Union by schedule scale		Phoenix area	250
Surveyors	Apprentice	Surveying	None	As required Union by schedule scale		Phoenix area	40

Table 8 (continued)

Job Title	Level of Training	Competencies (Skills Emphasized)	Need for Retraining	Length of Employment	Salary	Location	Number of Employees
Pipefitters	Apprentice	Install piping, welding	None	As required by schedule	Union scale	Phoenix area	750
Millwrights	Apprentice	Set and align heavy machines	None	As required by schedule	Union scale	Phoenix area	55
Carpenters	Apprentice	Formwork	None	As required by schedule	Union scale	Phoenix area	325
Electri-cians	Apprentice	Set elect, equip, raceways and wiring	None	As required by schedule	Union scale	Phoenix area	500
Laborers	Apprentice	General labor	None	As required by schedule	Union scale	Phoenix area	300
Boiler-maker	Apprentice	Install-weld pressure vessels	None	As required by schedule	Union scale	Phoenix area	70
						TOTAL	2,590

Source: J. R. McEntee, Bechtel Power Corporation, Letter, March 15, 1977.

and Arizona. Tables are provided which give information on employment and projected manpower needs by occupation for each state. The projections are for 1975 to 1977. Manpower needs in energy-related occupations are not considered independently. A list of training institutions is provided and could prove helpful to educational planners considering implementation of nuclear technician programs.

When operating, the Arizona Nuclear Power Project will employ approximately 300 people at the Palo Verde Station--plans specify three nuclear generating plants at the Palo Verde Station. These 300 positions divide about equally into two categories: technical people and supervisory personnel and foremen. Table 9 provides a breakdown of the assignments of the technical people.

Arizona Public Service (APS) is the project manager for the Palo Verde Station; thus employees at the Palo Verde Station will be subject to the personnel policies of APS. Many of the technical people will be affiliated with unions and will be paid at the rate agreed upon in the company's contract with the union. Many of the craftsmen are promoted from lower positions within the company and receive on-the-job training at each level. As craftsmen are trained, they join the union--after obtaining employment at Arizona Public Service.

General minimum requirements for operators, technicians, and repairmen working in a nuclear power generating plant are outlined in a publication of the American National Standards Institute (ANSI) titled Selection and Training of Nuclear Power Plant Personnel. The pertinent sections are quoted below.

> 4.5.1 Operators
>
> At the time of the initial core loading or appointment to the active position, operators to be licensed by the AEC shall have a high school diploma or equivalent and two years of power plant experience of which a minimum of one year shall be nuclear power plant experience. Further, before being acceptable for full responsibility in the job, they shall hold an AEC Reactor Operator's License.
>
> All operators, whether or not they are to be licensed by the AEC should have a high school diploma or equivalent, and should possess a high degree of manual dexterity

Table 9

Total Operating Staff
Palo Verde Nuclear Generating Station
Phoenix, Arizona

Job Title	1 plant 1982	2 plants 1984	3 plants 1986
Plant Manager	1	1	1
Assistant Plant Manager	1	1	1
Secretary	1	1	1
Technical Assistant	1	1	1
Operations Quality Assurance Engr.	1	1	1
Administrative Supervisor	1	1	1
Clerk Typist	4	4	4
Accounting Specialist	2	2	3
	12	12	13
Engineering			
Technical Supervisor	1	1	1
Instrument and Control Engineer	1	1	1
Computer Engineer	1	1	1
Instrument and Control Technician	5	7	10
Electrical Engineer	1	1	1
Assistant Engineer	0	1	1
Electrical Technician	5	5	5
Nuclear Engineer	1	1	1
Assistant Engineer	0	1	1
Mechanical Engineer	1	1	1
Assistant Engineer	0	1	2
	16	21	25
Operations			
Operations Supervisor	1	1	1
Shift Supervisor	6	6	6
Assistant Shift Supervisor	0	5	10
Senior Control Operator	5	10	14
Control Operator	5	10	14
Auxiliary Operator	5	10	14
Equipment Attendant	5	10	14
	27	52	73
Environmental Staff			
Health, Safety and Chemistry Supervisor	1	1	1
Chemistry Supervisor	1	1	1
Health Physics Supervisor	1	1	1
Senior Laboratory Technician	1	2	3
Chemistry and Health Physics Technician	2	2	3
	6	7	9

Table 9 (continued)

	1 plant 1982	2 plants 1984	3 plants 1986
Maintenance			
Maintenance Supervisor	1	1	1
Assistant Maintenance Supervisor	0	0	1
Electrical Foreman	1	1	1
Electrician	2	3	4
Electrical Helper	2	3	4
Mechanical Foreman	1	1	2
Plant Mechanic	2	3	4
Welder	2	3	4
Machinist	2	3	4
Maintenance Helper	2	3	10
Janitor	2	2	3
Storekeeper	1	1	2
Warehouseman	2	2	2
	20	26	42
TOTAL	77	118	162

Source: Arizona Nucelar Power Project. Preliminary Safety Analysis Report for Palo Verde Station, Sec. 13. September 1974.

and mature judgement. Selection interviews and examinations should be used for all operators to aid in determining individual ability to progress to high levels of responsibility and to eventual AEC licensing.

4.5.2 Technicians

Technicians in responsible positions shall have a minimum of two years of working experience in their specialty. These personnel should have a minimum of one year of related technical training in addition to their experience.

4.5.3 Repairmen

Repairmen in responsible positions shall have a minimum of three years in one or more crafts. They should possess a high degree of manual dexterity and ability and should be capable of learning and applying basic skills in maintenance operations (1971, p. 8).

Ultimately, the Palo Verde Station will employ 75 licensed operators. A reactor simulator has been purchased for training purposes. The ANSI standard recommends that one month's training be considered equal to three month's experience in either a nuclear power plant or in such non-power plant work as test, research, or production reactors. The standard also specifies that "only one year of such equivalent simulator training shall be acceptable toward the total nuclear experience qualification" (1971, p. 7).

Of the remaining technical people employed for operating the nuclear plant, the following general areas of competence will be required. The 45 to 60 maintenance people employed by the project will be machinists, mechanics, and electricians (a knowledge of electronics is not required). The skills needed will include repairing pumps and valves and welding. Approximately 25 instrumentation technicians will be needed to maintain the control instruments. Also employed will be approximately 18 to 20 chemical and health physics technicians and 3 or 4 computer tecnnicians. It is expected that many of these people will be transferred from the Four Corners Plant.

One other nuclear operation can be considered here: the increased manpower needs for the Carlsbad, New Mexico, area

which would result from development of the nuclear waste disposal site in that area. This waste disposal project is still in the research stage. Sandia Laboratories is presently in the process of refining the "conceptual design, construction and program schedule, and preliminary operation plans"(Weart, Letter, undated [1977]). Projections for construction (1979-83) and operation are shown in Table 10. While the project is largely designed for disposal of nuclear wastes from the defense industry, Sandia's contract with ERDA specifies that the design be made compatible for disposal of high-level nuclear waste derived from the nuclear power industry.

Solar

Solar energy seems to be one of the most promising emerging energy sources in New Mexico and Arizona. Table 11 displays occupational opportunities in the solar energy industry that are expected to emerge in the next 5 to 10 years in New Mexico and Arizona. Some difficulties were experienced in interpreting job titles because jobs were referred to by several names. However, after many attempts, it was decided to fit all studied solar energy job titles into eleven categories. The categories are as follows: assembling, installation, sales, technician, drafting, engineering, architecture and planning, research and development, small job contractor, solar furnace operator, and inspection of installation. Within each category, several subdivisions were incorporated. These classifications were cleared through the Employment Security Commission of New Mexico.

Table 10

Projection of Manpower Needs
Carlsbad Nuclear Waste Disposal Project

Construction, 1979-83		Operation, 1983-95	
Surface Construction	530	Administration and Professional	145
Underground Construction	190	Maintenance	70
Construction Field Engineering	20	Waste Handlers	75
		Mining	90*
TOTAL	740	TOTAL	380*

*From 1995 to decommissioning (approximately 2010), mining will reduce to 20 employees, for a total of 310 employees.

Source: Wendell D. Weart, Letter, undated [1977].

Table 11

Job Titles and Projected Number of Employees

Solar

Job Title	Competencies	New Mexico		Arizona		Total	
		Sam.	Pop.	Sam.	Pop.	Sam.	Pop.
Assembling							
Assemblers	sheet metal, soldering	40	88	4	27	44	115
Manufacturing Apprentice	brazing & welding,	20	44	-	-	20	44
Fabrication Welders	machine operation	3	7	5	33	8	40
Foreman	manufacturing process	-	-	1	7	1	7
Production Manager	technical and	-	-	1	7	1	7
Laborers	industrial	-	-	64	427	64	427
Installation							
Install and Service	knowledge of system, pipe fitting, air conditioning, electrician, soldering, welding, controls, sheet metal, plumbing, copper pipe, sizing of systems	30	67	51	340	81	407
Installation Contractor		-	-	1	7	1	7
Apprentice		15	33	-	-	15	33
Foreman		5	11	-	-	5	11
Supervisor		2	4	-	-	2	4
Master Plumber		-	-	2	14	2	14
Plumber	systems	4	9	1	7	5	16
Pipefitter		-	-	10	67	10	67
Carpenter		3	7	-	-	3	7

Table 11 (continued)

Job Title	Competencies	New Mexico Sam.	New Mexico Pop.	Arizona Sam.	Arizona Pop.	Total Sam.	Total Pop.
Engineering							
Engineer		-	-	25	167	25	167
Mechanical	design & heat transfer	25	56	5	33	30	89
Materials	heat transfer materials, solar energy systems, heat loss	-	-	1	7	1	7
Solar		1	2	4	27	5	29
Electrical		-	-	4	27	4	27
Mechanical or Civil		1	2	-	-	1	2
Civil		3	7	-	-	3	7
Aids	drafting & design	3	7	-	-	3	7
Research and Development							
Chief	math and physics, shop experience, drafting, welding	1	2	1	7	2	9
Small Job Contractor	cost estimation, purchasing	3	7	-	-	3	7
Sales							
Salesman		5	11	18	120	23	131
Sales and Marketing	engineering or technical ability	6	13	-	-	6	13
Sales Representative	group dynamics	10	22	13	87	23	109
Sales Manager	marketing, business, math	-	-	9	60	9	60

Table 11 (continued)

Job Title	Competencies	New Mexico Sam.	New Mexico Pop.	Arizona Sam.	Arizona Pop.	Total Sam.	Total Pop.
Technical							
Technician	math, electrical background	-	-	1	7	1	7
Shop	mechanics, sheet metal, plumbing	-	-	2	14	2	14
Instrument		2	4	1	7	3	11
Heat, Ventilation, Air Conditioning		-	-	15	100	15	100
Solar	inspection, group dynamics, special training	1	2	1	7	2	9
Drafting							
Draftsman	understand piping systems	2	4	7	47	9	51
Architecture and Planning							
Architect	human relations	2	4	7	47	9	51
Planner	community planning	-	-	2	14	2	14
Solar Furnace Operator	optics	7	16	-	-	7	16
Inspection of Installation	mechanical ability, human relations	3	7	-	-	3	7
	TOTAL	197	436	256	1,714	453	2,150

The projected employment total for the organizations sampled was 453. If this projection is extended to cover the total population of the study, the projected number of employees in the solar industry increases to 2,150. It is expected that 436 jobs in New Mexico and 1,714 jobs in Arizona will be available in the solar energy industry within the next 5 to 10 years. Experts in the field considered this projection reasonable.

Of the eleven major titles listed in Table 11, the assembling, installation, engineering, sales, and technician categories are significant. These five categories comprise 92.8 percent of the total labor force projected for the solar energy industry.

The assembling process in this industry will absorb a large portion of the employees. About 29.8 percent of all the labor force projected will work within this category. Three-fourths of the jobs were forecast to be in Arizona. Six job titles appear under the assembling category: assembler, manufacturing apprentice, fabrication welder, foreman, production manager and laborer. Competencies required for these jobs cover an array of skills: sheet metal; soldering; brazing; welding; machine operation; and manufacturing process, mechanical, and industrial skills.

Except for the managerial post, a four-year college education is not needed for these jobs. Laborers constitute 66.7 percent of the assembling category. On-the-job training may suffice for this kind of employment and for the manufacturing apprentices. The remainder of this category, which makes up about one-third (33.3 percent), need adequate training outside the job site. For this type of job, schools should prepare programs which will provide opportunities for students to acquire the needed skills.

By and large, the job titles in the assembling category emphasize practice and experience rather than formal education. Not only can this be interpreted from the figures in Table 11, but it was mentioned by the respondents in the field.

Installation, the second category, accounts for 26.3 percent of the total projected manpower in the solar energy industry. The category includes within its domain installer, service person, installation contractor, installation apprentice, foreman, supervisor, plumber, master plumber, carpenter, and pipe fitter. Employers demand a range of competencies and skills from their prospective employees. The major skills mentioned include knowledge of systems, pipe fitting, air conditioning, electricity,

soldering, welding, sheet metal, plumbing, copper pipe, and sizing of systems. Duplication of skills and competencies are noticed between assembling and installation, because some jobs require a combination of skills.

Installers and service people in this category constitute the largest percentage (71.9 percent). Arizona takes the lion's share in these jobs, as it did with the laborers in the assembling category. It was estimated that approximately the same number of people are required to service equipment as are required for installation.

In the training of the prospective employees, employers stressed the teaching of a systems approach. To visualize the solar energy installation as a network of units in which each unit should function properly for the total health of the system is essential. Employers complained of the fact that ignorance of systems concepts among their employees cost them a great deal of money, energy and time. This new element deserves the program developer's attention. It requires an in-depth study because it is related to attitude formation.

The engineering category encompasses 15.6 percent of the total solar manpower projection. The job titles within this category include engineer, mechanical engineer, materials engineer, solar engineer, electrical engineer, civil engineer, and engineering aids. These job titles refer to highly skilled professionals. Engineering aids could be associate degree holders.

The solar energy industry at present requires a larger percentage of engineers than are employed in the construction of either a coal gasification plant or a nuclear power plant. As previously mentioned, engineers will constitute 15.6 percent of the work force in the solar energy industry, whereas they constitute only about 6.9 percent of the employees for a nuclear plant. Different types of engineers will probably be attracted to solar energy, because of the variety of engineering occupations that will be available. For instance, presently there are more than one dozen areas in solar energy. The Arizona Solar Energy Directory (November 1976) lists the following areas of activity: collectors, components, cooker/ovens, instrumentation, photovoltaics, space heating systems, swimming pool heating systems, water heating systems, architect/designers, contractors, engineer/scientists, research and development, and test facilities. Solar energy provides an expanding labor market which will probably provide a high percentage of new jobs for trained people.

The sales category accounts for 14.6 percent of the total projected manpower demand in the solar energy industry. The job titles are salesman, sales representative, and sales manager. This group of jobs requires training in both the physical sciences and the social sciences. Specific competencies and skills emphasized by employers include engineering or technical ability, group dynamics, marketing, business, and mathematics. Identifying salable goods, discovering potential consumers, and attracting their attention requires extensive knowledge of the pyschology and tactics of business. Thus, a four-year college education seems appropriate for preparation for these positions.

About one-third (34.8 percent) of the sales jobs fall under the title of sales representative. This, to a certain extent, indicates the important role that the sales representative plays in the solar energy industry.

The fifth job category that deserves close attention is the technical category. In this area, new occupations will probably emerge. Job duties for this category include applying the theoretical knowledge of science, engineering, mathematical or drafting design, solving practical problems related to assembly, installing and repairing solar energy systems, and developing and establishing testing methods. At present, the category consists of five job titles. These are technician; shop technician; instrument technician; heat, ventilation, and air conditioning technician; and solar technician. The technician cluster is incompletely defined but promises potential growth. Further study must be done to determine more definite training needs.

The competencies recommended cover technical background mechanics, sheet metal, group dynamics, and plumbing. Some employers stated that special training was essential for jobs such as solar technician and instrument technician. Here is a new field that invites the curriculum developer to examine the educational implications and to design appropriate programs of study.

It should be noted that in the Phoenix area, several respondents mentioned that the heat, ventilation, and air conditioning technician might require some retraining. Most respondents in that area stated that they would provide retraining for present employees. It was also pointed out that the vocational schools were overproducing heat, ventilation, and air conditioning technicians at present.

Almost all the jobs projected for the technician category (95.7 percent) will be located in Arizona. New Mexico employers rarely mentioned these occupations in their responses. This could perhaps be attributed to the fact that solar energy businesses are growing more rapidly in Arizona. As a matter of fact, the Phoenix area is witnessing the growth of a considerable number of buildings that are utilizing solar heating systems. There has been a gas moratorium on new gas hookups in the developing areas surrounding the Phoenix metropolitan area. Many new homes and even schools have, consequently, turned to solar energy for space heating and for heating of pools.

According to the data gathered, respondents suggest that a solar technician should be able to communicate effectively with the utilizers of solar energy. Although his field involves technical or engineering skills, he has to have a knowledge of the art of dealing with people. The need for an understanding of group dynamics has been mentioned by employers in this and in the sales category. This fact indicates a trend towards emphasizing the learning of effective communication in the solar energy industry.

Besides the five categories analyzed above, six other categories are listed in Table 11. These job titles make up 7.2 percent of the projected labor force. These six job titles include research and development chief, small job contractor, draftsman, architect and planner, solar furnace operator, and inspector of installation. Skills needed for the research and development chief are mathematics, physics, shop experience, drafting, and welding. These are science-based skills. The small job contractor occupation emphasizes the skill of cost estimation and a knowledge of business. Respondents stressed that draftsmen in solar energy installation should have a fair knowledge of piping systems. Draftsmen should be geared toward solar energy applications. Architects and planners must have considerable education. Their work requires skill in dealing with people and planning for usable services. The research and development chief, small job contractor, architect, and planner must be four-year college graduates. The solar furnace operator should have a background in physics and the inspector of installation should possess mechanical ability and skill in human relations. In terms of education, a draftsman, a solar furnace operator, and an inspector of installation need not be graduates of four-year college programs.

Waste Products

Table 12 exhibits the manpower requirement for operating a proposed solid waste generating plant. Required skills are

diversified, and 45 employees are needed to man the plant. Boiler operators constitute 26.6 percent of the total work force.

Table 13 illustrates the competencies of waste product researchers in New Mexico. These are primarily highly trained people in science and engineering.

Wind

It was surprising that so few people were available to participate in the study in the field of wind energy. Initially, it was assumed, based on the literature reviewed, that a good number of people who were interested in wind energy could be identified. However, those who were contacted replied negatively. The main reason mentioned in their reply was that wind was not their area of concern, despite the fact that their names were recorded in the New Mexico Energy Research Resource Registry (December 1975) as experts in wind power. The only interview conducted on wind energy was at the campus of New Mexico State University, with a windmill technology instructor.

In answer to the question concerning organizations and agencies in New Mexico or Arizona engaged in the wind power industry, the respondent replied that none were, except the

Table 12

Manpower Needs
Proposed Solid Waste Generating Plant
for Phoenix, Arizona

Job Title	Number of Employees
Scale Operator	2
Traffic Director	1
Crane Operator	4
Line Operator	4
Laborer	4
Mechanic	4
Electrician	2
Ferrous Loader	2
Foreman	2
Boiler Operator	12
Relief Operator	4
Turbine Operator	4
TOTAL	45

Source: Henningson, Durham, and Richardson, "Proposal to City of Phoenix," 1976.

Table 13

Waste Product Researchers
New Mexico

Research Team	Number of Employees
Bio-Conversion Manager (Ph.D.)	1
Civil Engineer (Ph.D.)	2
Mechanical Engineer (Ph.D.)	1
Algalogist, Microbiologist, Physiologist (Ph.D.)	1
Biologist	1
Production	
Research Technician (M.Sc.)	6
Production Manager	1
Algalogist, Culturing (B.Sc. & Training)	1
Civil or Mechanical Engineer	1
TOTAL	15

Extension Department at New Mexico State University, which offered a short course some time in 1976.

The manpower needs in the wind energy field are negligible. However, based on the short course delivered in the Extension Department, the respondent proposed the job titles that appear in Table 14.

There are few wind energy activities in Arizona because there is not enough constant wind available (Reed, 1977, pp. 7-10). With respect to New Mexico, some research is in progress.

Conclusion

Generally, there seems to be a trend away from hiring highly skilled people as an industry moves from the research and development stage to the production stage. In production, the ratio of technicians to engineers increases and, of course, more assembly type work is performed. Thus, in the research laboratories, highly trained personnel are employed. And energy sources which are still in the research and development stage employ highly trained personnel. In the area of waste products, many of the personnel employed can be expected to be highly qualified. So, too, in the solar industry, where a high proportion of engineers are employed, comparatively speaking. The one big exception to this trend can be seen in the nuclear industry. Because of the stringent safety standards in that industry, the number of employees is

minimized and that minimization results in a need for more specialized technical training.

Table 14

Proposed Job Titles in Wind Energy
New Mexico

Job Title	Competencies	Number of Employees
Windmill Technician	Electro-mechanics	N.A.
Wind Driller	Knowledge of hydrolics	N.A.
Windmill Construction Worker		N.A.
Windmill Maintenance Worker		N.A.

Chapter 4

Summary and Recommendations

For education decision makers and curriculum planners to make wise choices about what new technical training programs should be implemented, they must know what skills will be in demand in the labor market. With the increased emphasis on developing alternative energy sources, new skills may be needed. And the vocational and technical schools at the post high school level can provide the necessary training only if the new skills have been identified and training programs prepared.

The purpose of the Energy Manpower Research Project was to identify what skills would be needed in emerging energy sources and to discover any new occupations for which additional training would be needed. To succeed in projecting manpower needs for the next 5 to 10 years, energy policies had to be examined. Energy policies play an important role in determining which alternative energy sources can be successfully developed at a particular time.

Procedure

To obtain the desired information about energy policies and manpower needs, an interview schedule was used. Interviewers met with employers in Arizona and New Mexico and recorded their responses to questions about energy policies and manpower needs. The information reported here represents a summary of those responses. The information gathered represents the perceptions of employers and researchers about what policies they believe affect how a particular energy source will develop and what their manning needs will be within the next ten years.

The energy sources investigated in this study were coal gasification, geothermal, nuclear, solar, wind, and waste. In the cases of coal gasification and nuclear power generation, all employers with operations in Arizona and New Mexico were contacted. In Arizona, all persons involved in the development of geothermal energy were contacted. However, in New Mexico, where 19 organizations were identified as involved in the development of geothermal energy, a 50 percent random sample was taken and the organizations contacted.

All organizations working with wind energy and utilization of waste products as an energy source were contacted. Few individuals or businesses were found that were involved in these two areas, although research is being conducted. It is

doubtful that a large number of openings will occur in either area within the next 10 years. And what openings do occur will probably require highly trained, specialized individuals.

A number of occupations are developing in the solar energy industry. In Arizona, 169 businesses and agencies were identified; 51 were identified in New Mexico. Because of budget limitations, all organizations could not be contacted. Therefore, 15 percent of the organizations in Arizona and 45 percent of those in New Mexico were randomly sampled. Included in the sample were architects; consulting engineers; solar equipment manufacturers, distributors, and marketing firms; and research and development personnel. Also contacted were state agencies in Arizona and New Mexico, utility companies, and research and development laboratories.

The findings fall under two general categories: energy policies and manpower needs.

Energy Policies

The respondents were, generally, very concerned about what they believe is the present lack of a national energy policy. Most stated that the Federal government must accept a leadership role in forming energy policies and a national energy plan. It was suggested that if a clearly defined national energy plan existed people would know which way to go. Implicitly, then, the lack of Federal policy has slowed down development of alternative energy sources. The risk, it seems, is too great. In many cases, large amounts of capital must be invested now, but the returns are too uncertain because the future is too uncertain. Respondents were pleased that the present manpower needs survey was being done. And most were anxious to participate. It was suggested that a manpower needs survey could affect future policy decisions.

A number of existing policies were mentioned which respondents believe have affected the development of alternative energy sources, some positively, some adversely. For example, twelve respondents believe that tax incentives have had a positive affect on the development of solar energy in Arizona and New Mexico. However, it was maintained that the present incentives are not sufficient to induce middle income families to consider purchasing solar equipment. Also, it was pointed out that in New Mexico, if solar heating is added to one's home, the value is added to the property tax evaluation--a negative tax inducement. Present zoning laws in both states can present problems.

Environmental regulations were mentioned as government policies which have slowed development of coal gasification

and geothermal energy. The existence of affirmative action laws and other regulations relating to manpower have influenced some businessmen to limit the size of their operations. While saying they need some type of financial assistance, many wish to avoid the bureaucratic red tape they see as involved in complying with most Federal regulations or as required to obtain Federal monies. In all, 40 different responses were elicited to the question about existing energy policies.

The question asking about emerging energy policies elicited 47 different responses. Respondents working in every energy source suggested that some type of Federal monetary inducement was needed. Frequently, the aid mentioned was some kind of tax relief. Other policies suggested included that environmental regulations be simplified, that the general public be educated about how solar energy can best be utilized, that financing for solar homes be made more available, that prices on conventional fuels be set to cover the actual costs, and that natural gas be deregulated.

Many of the respondents working in the solar and geothermal industries believe that present governmental policies favor the large utility companies in such a way that it is difficult for solar energy and other alternative energy sources to be competitive. The utility companies argue that the investments they are required to make are so large that they would be unable to raise the money needed to build new plants were they not assured of a certain income. Spokesmen for the utility industry did stress the need for development of alternative energy sources. Perhaps policies promoting an integration of alternative energy sources with existing industries should be explored.

Finally, many respondents mentioned conservation as an important energy policy. Again, it was suggested that the Federal government must provide leadership if conservation is to become an important energy policy.

Policies were examined in this study because policy was considered a key variable in deciding what energy sources will be developed. In the light of pertinent policy issues, solar energy seems especially attractive as an energy source in Arizona and New Mexico. This is primarily for heating and cooling purposes and may not be true for production of electrical energy. It has few of the drawbacks associated with other alternative energy sources. Problems concerning distribution hinder development of waste products and geothermal energy. All are suitable sources if they can be used at the site where they occur, but solar energy occurs

everywhere. And while the cost of solar energy equipment is high, it can, for many uses, still be attractive. Especially where natural gas is not available, solar energy equipment is being installed for heating purposes.

Also, solar energy is attractive if one considers conservation a key issue, and it is attractive from an environmental point of view. As people learn more about solar energy and as a trained labor force becomes available, it may well develop at an increasingly rapid rate. Thus if one considers feasibility from the point of view of policy matters, solar energy appears to be a likely candidate to play an important role as a developing energy source for heating and cooling purposes within the next 5 to 10 years. Next it must be determined if new skills or new occupations will be needed in the solar energy industry.

Manpower Training Needs

Table 15 lists all job titles as they were given to the interviewers. Projections of employees needed are given by job title and energy source. The last column gives the total number projected by job title for all energy sources. An effort was made when possible to group the job titles into occupational clusters. Thus, all engineers are listed together.

It should be noted that in most cases the job titles refer to conventional trades and skills. In some cases, a certain amount of new training will be needed, but can be provided on the job. Certain trades, especially pipe fitter (1,547), pipefitter/welder (440), electrician (891), boilermaker (183), and boilermaker/welder (85), have already been noted as perhaps in short supply. A glance at the "Total" column in Table 12 suggests that certain of the traditional occupations will be in demand during plant construction. However, entry into these trades, for construction purposes, is controlled by union membership. Thus, educational planners must consider union policies when implementing training programs to prepare people to enter these trades. However, during the construction period, there may well be a great enough demand that not all needs can be met by the unions, so that training programs could prove beneficial.

Besides those listed above, several other job titles related to plant construction denote training and skill: carpenters (524), ironworkers (490), and operating engineers (435). Other conventional job titles requiring a fairly large number of workers are cement masons (184), millwrights (185), and teamsters (180). Also, a large number of plant mechanics (223) will be employed when the plants begin

Table 15

Summary of Manpower Needs
by Job Title and Energy Source

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Engineer	-	192	30	2	6	167	-	397
Civil Engineer	-	-	-	-	-	7	1	8
Computer Engineer	-	-	-	1	-	-	-	1
Drilling Engineer	-	-	-	-	4	-	-	4
Electrical Engineer	-	-	-	2	-	27	-	29
Instrument and Control Engineer	-	-	-	1	-	-	-	1
Materials Engineer	-	-	-	-	-	7	-	7
Mechanical Engineer	-	-	-	2	-	89	1	92
Mechanical or Civil Engineer	-	-	-	-	-	2	1	3
Nuclear Engineer	-	-	-	2	-	-	-	2
Reservoir Engineer	-	-	-	-	2	-	-	2
Solar Engineer	-	-	-	-	-	29	-	29
Engineering Aid	-	-	-	-	-	7	-	7

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Carpenter	192	325	-	-	-	7	-	524
Boilermaker	113	70	-	-	-	-	-	183
Boilermaker/Welder	85	-	-	-	-	-	-	85
Millwright	130	55	-	-	-	-	-	185
Millwright/Welder	30	-	-	-	-	-	-	30
Ironworker	240	250	-	-	-	-	-	490
Pipefitter	730	750	-	-	-	67	-	1547
Pipefitter/Welder	440	-	-	-	-	-	-	440
Teamster	80	100	-	-	-	-	-	180
Laborer	515	300	-	-	-	427	4	1246
Electrician	363	500	17	9	-	-	2	891
Sheet Metal Worker	30	-	-	-	-	-	-	30
Bricklayer	20	-	-	-	-	-	-	20
Cement Mason	154	30	-	-	-	-	-	184
Painter	61	35	5	-	-	-	-	101

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Asbestos Worker	121	-	-	-	-	-	-	121
Surveyor	-	40	-	-	-	-	-	40
Chemist	-	-	5	-	-	-	-	5
Health Safety and Chemistry Supervisor	-	-	-	1	-	-	-	1
Chemistry Supervisor	-	-	-	1	-	-	-	1
Health Physics Supervisor	-	-	-	1	-	-	-	1
Laboratory Technician	-	-	14	-	-	-	-	14
Senior Laboratory Technician	-	-	-	3	-	-	-	3
Chemistry and Health Physics Technician	-	-	-	3	-	-	-	3
Safety Technician	-	-	10	-	-	-	-	10
Technical Supervisor	-	-	-	1	-	-	-	1
Process Operator	-	-	350	-	-	-	-	350
Operations Supervisor	-	-	-	1	-	-	-	1
Shift Supervisor	-	-	-	6	-	-	-	6

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Assistant Shift Supervisor	-	-	-	10	-	-	-	10
Senior Control Operator	-	-	-	14	-	-	-	14
Control Operator	-	-	-	14	-	-	-	14
Auxiliary Operator	-	-	-	14	-	-	-	14
Plant Mechanic	-	-	213	6	-	-	4	223
Machinist	-	-	25	4	-	-	-	29
Welder	-	-	34	4	-	-	-	38
Welder, Fabrication	-	-	-	-	-	40	-	40
Maintenance Supervisor	-	-	-	2	-	-	-	2
Maintenance Helper	-	-	-	10	-	-	-	10
Janitor	-	-	-	3	-	-	-	3
Storekeeper	-	-	-	2	-	-	-	2
Warehouseman	-	-	-	2	-	-	-	2
Communication Technician	-	-	5	-	-	-	-	5
Corrosion Technician	-	-	3	-	-	-	-	3

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Instrument Technician	-	-	15	-	10	11	-	36
Instrument and Control Technician	-	-	-	10	-	-	-	10
Electrical Technician	-	-	5	-	-	-	-	5
Technician	-	-	-	-	-	7	-	7
Equipment Attendant	-	-	-	14	-	-	-	14
Heat, Ventilation, Air Conditioning Technician	-	-	-	-	-	100	-	100
Solar Technician	-	-	-	-	-	9	-	9
Shop Technician	-	-	-	-	-	14	-	14
Research and Development Chief	-	-	-	-	-	9	-	9
Small Job Contractor	-	-	-	-	-	7	-	7
Architect	-	-	-	-	-	51	-	51
Planner	-	-	-	-	-	14	-	14
Draftsman	-	-	3	-	-	51	-	54
Solar Furnace Operator	-	-	-	-	-	16	-	16

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Salesman	-	-	-	-	-	131	-	131
Sales and Marketing	-	-	-	-	-	13	-	13
Sales Representative	-	-	-	-	-	109	-	109
Sales Manager	-	-	-	-	-	60	-	60
Operating Engineer	300	135	-	-	-	-	-	435
Equipment Operator	-	-	3	-	-	-	-	3
Scale Operator	-	-	-	-	-	-	2	2
Traffic Director	-	-	-	-	-	-	1	1
Crane Operator	-	-	-	-	-	-	4	4
Line Operator	-	-	-	-	-	-	4	4
Boiler Operator	-	-	-	-	-	-	12	12
Relief Operator	-	-	-	-	-	-	4	4
Turbine Operator	-	-	-	-	-	-	2	2
Geologist	-	-	-	-	14	-	-	14
Production Foreman	-	-	-	-	4	-	-	4
Foreman	-	-	-	-	-	7	2	9

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Production Manager	-	-	-	-	-	7	1	8
Roughneck	-	-	-	-	22	-	-	22
Drilling Superintendent	-	-	-	-	4	-	-	4
Drilling Crew	-	-	-	-	30	-	-	30
Assembler	-	-	-	-	-	115	-	115
Manufacturing Apprentice	-	-	-	-	-	44	-	44
Installer and Serviceman	-	-	-	-	-	407	-	407
Installation Contractor	-	-	-	-	-	7	-	7
Installation Apprentice	-	-	-	-	-	33	-	33
Installation Foreman	-	-	-	-	-	11	-	11
Installation Supervisor	-	-	-	-	-	4	-	4
Plumber	-	-	-	-	-	16	-	16
Master Plumber	-	-	-	-	-	14	-	14
Installation Inspector	-	-	-	-	-	7	-	7
Ferrous Loader	-	-	-	-	-	-	2	2
Bio-conversion Manager	-	-	-	-	-	-	1	1

Table 15 (continued)

Job Title	Construction		Operation					
	Coal Gasification	Nuclear	Coal Gasification	Nuclear	Geothermal	Solar	Waste	Total
Biologist	-	-	-	-	-	-	1	1
Algalogist, Microbiologist, Or Physiologist	-	-	-	-	-	-	1	1
Research Technician	-	-	-	-	-	-	1	1
Algalogist, Culturing	-	-	-	-	-	-	1	1

operation. Thus the labor market for workers trained in conventional skills will be quite good, especially while large plants are under construction. A smaller number of people can hope to find permanent employment when plants begin operation.

For operation of the coal gasification plant, 350 process operators will be trained. While this occupation may be regarded as a new occupation, the training required will be provided on the job. For operation of a nuclear plant, 73 operators will be needed. Again, these people will be trained on the job, although some prior training could be acquired in a training program if a simulator is used by the training institution. However, it appears likely that existing training programs will suffice.

Only one other emerging energy industry promises to employ a large number of people within the next 5 to 10 years--the solar energy industry. The occupation requiring the largest number of people will be that of installation and service (407). Salesmen (131); sales representatives (109); assemblers (115); and heat, ventilation, and air conditioning technicians (100) are also projected to require substantial numbers of workers. And a number of these workers will require specific skills and training. Sales personnel will be expected to know how to size a particular system according to the requirements of specific structures. However, some difficulty arises if one contemplates planning a course to teach salesmen the proper methods. The problem is that there are in existence a substantial number of different solar systems, systems so different that only a general training course could be provided. Courses in mathematics and human relations could be of use, as could a course describing what can be done with solar energy.

In reference to a number of the job titles associated with solar energy, respondents mentioned that a knowledge of systems theory was needed. It is generally believed that all persons who install or service solar energy systems of any kind, and even salesmen, must have a comprehensive understanding of how a total system works, of the theory which lies behind any specific solar system. Thus here is a training need which can best be answered by vocational/technical, post high school training programs.

There appears to be a need for a number of engineers in the solar energy industry. In fact, the present study projected a need for a total of 575 engineers over the next 5 to 10 years in all areas examined. Of this total, 328 engineers, or 57 percent, are projected as needed by the solar energy industry. This number is significant even if one

considers that as production becomes more routine, training requirements are usually lower. Again, some special training will be needed for those who plan to enter the solar energy industry.

Conclusions

The following specific conclusions were reached on the basis of the findings presented in chapters 2 and 3.

The tax incentives provided by the states of New Mexico and Arizona for the development and utilization of solar energy will have an impact on the creation of jobs. About 24 percent of the respondents considered the tax incentive policies encouraging; another 34 percent responded that the existing tax incentives were inadequate and should be liberalized.

That the rules and regulations of the Environmental Protection Agency impede progress of geothermal energy exploration and development is an opinion shared by about 25 percent of the respondents.

The high capital cost of nuclear power plants is largely caused by the 10-year lead time required for building a plant.

Standardization in the solar energy industry is desirable because such a process would save valuable resources of developers as well as of users.

New energy policies should include increased government grants, subsidies, tax relief, and insured low interest loans for the development of emerging energy sources.

Of the six emerging energy sources studied in this project, solar energy, nuclear power generation, and coal gasification (provided Federal support is extended) appear most likely to provide a considerable number of jobs in the next 5 to 10 years.

New jobs in the geothermal energy industry in New Mexico and Arizona do not seem promising. It is expected that jobs in this field which will be available during the coming decade will be filled by labor transfer from existing petroleum industries.

Pipefitters, pipefitter/welders, electricians, ironworkers, process operators, and plant mechanics are anticipated to be in high demand in the proposed coal gasification projects.

Pipefitters, electricians, carpenters, and ironworkers will be in demand during construction of nuclear power plant projects.

No observable need for manpower training was noticed in either wind power or waste product usage in New Mexico or Arizona.

It was estimated that about 2,150 new jobs will be created in the next five to 10 years as a result of growth in the solar energy industry in New Mexico and Arizona. Numerous competencies and special skills will be required by these new jobs. Occupational competencies needed will be in sheet metal work, soldering, brazing, welding, machine operation, knowing systems concepts, pipefitting, woodwork, air conditioning, electrical work, plumbing, design, understanding heat transfer, understanding human relations, and knowing basics of mathematics and physics.

This study indicates that a four-year college education is not essential for approximately 60 percent of all projected jobs in solar energy, 85 percent of all coal gasification jobs, and 80 percent of all nuclear power generation jobs.

Recommendations

Based on the previous findings and conclusions presented, the following recommendations are proposed.

1. Before training programs are initiated, surveys of training facilities and an analysis of existing manpower conditions should be conducted.

2. To avoid unnecessary duplication of efforts, existing educational institutions should try to find means of cooperating amongst themselves to determine responsibilities for training in emerging energy occupations.

3. Competencies and skills which are essential for success in most of the solar energy, nuclear, and coal gasification occupational projections, such as sheet metal work, soldering, brazing, welding, machine operation, pipefitting, air conditioning, electricity, plumbing, woodworking, fitting of copper pipe, sizing systems, and understanding system concepts need to be emphasized in the curriculum of post high school vocational/technical institutions.

4. To meet the rise in employment opportunities in the solar energy industry, nuclear power industry, and coal gasification, secondary education programs should encourage student career exploration. Also, post high school vocational/technical institutions should help students to acquire occupational skills in pipefitting, welding, electricity, woodworking,

boilermaking, iron working, sheet metal working, mechanics, instrumentation, installation, and plumbing.

5. As a matter of effective curriculum policy, educational institutions should seek constant input from organizations which use such skills. Therefore, it is recommended that concerned schools should continue to strengthen existing relationships with industry.

6. A balance between theoretical and practical training in emerging energy occupations is recommended. The balance should be sought according to the nature of the skill. For example, sheet metal work is a practical skill whereas mathematics is to a certain extent a theoretical skill.

7. Educational institutions should participate actively in educating the public about energy conservation in general and the utilization of solar energy in particular. Offering evening courses on energy, holding energy orientation programs, and sponsoring public lectures on energy are ways educational institutions may help make the public aware of the energy shortage.

8. Skills in mathematics, physics, and human relations are curriculum areas which deserve consideration in preparing individuals for projected solar energy jobs.

9. An in-depth occupational analysis of solar energy jobs should be conducted in order to develop adequate training programs.

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APPENDIX A

Advisory Board
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APPENDIX B

Interview Schedule

NEW MEXICO STATE UNIVERSITY

Energy Manpower Training Research Project

Date_____

Name of Interviewer_____

Type of Agency or Organization_____

_____

1. Company (firm, organization, agency or service)

   A. Name of Company_____

   B. Address_____

      City/State_____

   C. Name of person interviewed_____

   D. Telephone number of person interviewed_____

   E. Position of person interviewed_____

   F. Describe the functions of business or services as related to emerging energy.

      _____

      _____

      _____

   G. Main function(s) of company (check one or more)

      ___1. Sales
      ___2. Services
      ___3. Purchasing
      ___4. Manufacturing
      ___5. Marketing
      ___6. Processing
      ___7. Government (Federal, state, local)
      ___8. Other

H. Years company has been in business_____

I. Percent of gross income that is energy oriented

_____

2. In New Mexico or Arizona, what energy policies related to manpower needs exist now?

3. With developing sources of energy, do you foresee new energy policies emerging?

4. Competencies of employees (projected)

Job Title	Level of Training	Competencies	Need for Retraining	Length of Employment	Salary	Location	No. of Employees

83

5. What other businesses could give us the kind of information we need?

APPENDIX C

Organizations Interviewed

Coal Gasification

New Mexico

New Mexico Bureau of Mines and Mineral Resources (NMI)
Socorro, New Mexico 87801

Other

El Paso Natural Gas Company
El Paso, Texas 79901

Geothermal

Arizona

Arizona State University
Room 640 - Physical Science Building, F Wing
Tempe, Arizona 85281

John L. Burton, Jr.
Phoenix, Arizona 85001

Geotermica
P. O. Box 1211
Litchfield Park, Arizona 85340

Nix Drilling Company
1600 N. Broad
Globe, Arizona 85501

University of Arizona
Geoscience Department
Tucson, Arizona 85721

New Mexico

Dikewood Industries, Inc.
1009 Bredbury Drive, S.E.
Albuquerque, New Mexico 87103

New Mexico Bureau of Mines and Mineral Resources (NMI)
Socorro, New Mexico 87801

New Mexico State University
Earth Science (Geophysics)
Las Cruces, New Mexico 88003

Sandia Laboratories
Albuquerque, New Mexico 87115

Other

Anadarko Production Company
P. O. Box 1330
Houston, Texas 77001

Union Oil of California
P. O. Box 7600
Los Angeles, California 90051

Nuclear

Arizona

Arizona Nuclear Power Project
Phoenix, Arizona 85036

New Mexico

New Mexico Bureau of Mines and Mineral Resources (NMI)
Socorro, New Mexico 87801

Public Service of New Mexico
P. O. Box 2267
Albuquerque, New Mexico 87103

Sohio Petroleum Company
6001 Marble N.E. Suites 15-26
Albuquerque, New Mexico 87103

Other

Bechtel Power Corporation
12400 E. Imperial Highway
Los Angeles, California 90650

Solar

Arizona

Arizona Engineering and Refrigeration
635 W. Commerce
Gilbert, Arizona 85234

Benham, Blair-Ditzler and Elling
4747 N. 22nd Street, P. O. Box 7395
Phoenix, Arizona 85016

Boyle Engineering
3625 N. 16th Street
Suite 107
Phoenix, Arizona 85016

Consolar Inc., Solar Energy Systems
800 West Panorama Road
Tucson, Arizona 85036

Delavan Electronics, Inc.
14441 N. 73rd Street
Scottsdale, Arizona 85254

Michael Frietas, Architect
10242 N. 58th Street
Phoenix, Arizona 85018

Goettle Brothers
2005 Indian School Road
Phoenix, Arizona 85015

Helio Associates, Inc.
Box 17960
Tucson, Arizona 85731

J & B Sales
3441 N. 29th Avenue
Phoenix, Arizona 85017

Leisure Pools, Inc.
1124 South Carolina Street
Mesa, Arizona 85201

Matrix
244 N. Country Club Drive
Mesa, Arizona 85201

Mesa Heating and Cooling
22 W. 8th Avenue
Mesa, Arizona 85201

Solar Building Systems
Suite 209/610 West Broadway
Tempe, Arizona 85281

Solar King
4002 East Grant Road
Tucson, Arizona 85716

Solar Systems of Arizona
7607 E. Greenway Road
Scottsdale, Arizona 85252

Solar Tech
Box J
Thatcher, Arizona 85552

Solar Therm, Inc.
14425 North Scottsdale Road, Suite 700
Scottsdale, Arizona 85260

Solux Corporation
1908 E. Buchanan Street
Phoenix, Arizona 85034

Southern Solar System
650 South Sixth Avenue
Tucson, Arizona 85701

Swim Chem Products
2445 N. 32nd Street
Phoenix, Arizona 85008

Swinghamers
3310 N. 27th Avenue
Phoenix, Arizona 85017

Tucson Community Development and Design Center
316 South Convent Street
Tucson, Arizona 85701

Young Construction
4733 W. Mercer Lane
Glendale, Arizona 85301

State Agency

Arizona Solar Energy Research Commission
1700 W. Washington
Phoenix, Arizona 85007

University of Arizona
Environmental Research Laboratory
Tucson, Arizona 85706

New Mexico

Albuquerque Western Solar Industries, Inc.
612 Comanche N.E.
Albuquerque, New Mexico 87107

Barkman Engineering
107 Cienega
Santa Fe, New Mexico 87501

L. W. Bickle and Associates
8100 Mountain Road N.E., Suite 105
Albuquerque, New Mexico 87110

Bridgers and Paxton Consulting Engineers, Inc.
213 Truman N.E.
Albuquerque, New Mexico 87102

Bruce Caird Realty, Inc.
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Albuquerque, New Mexico 87108

Canyon Research Company
133 Virginia N.E.
Albuquerque, New Mexico 87108

City of Albuquerque
Box 1293
Albuquerque, New Mexico 87103

Community Sciences Corporation
Corrales, New Mexico 57048

Delapp Engineering Corporation
1300 Luisa Street
Santa Fe, New Mexico 87501

Van H. Gilbert, Architect
418 Tulane
Albuquerque, New Mexico 87106

Gulfton Industries
1500 Central S.E.
Albuquerque, New Mexico 87108

K Tech Corporation
911 Pennsylvania N.E.
Albuquerque, New Mexico 87110

McDonnell-Douglas Corporation
Box 1850
Albuquerque, New Mexico 87101

Meda Inc.
4100 Edith N.E.
Albuquerque, New Mexico 87107

Metal Mart, Inc.
6139 Second Street N.W.
Albuquerque, New Mexico 87107

Antoine Preddock, Architect
300 12th Street N.W.
Albuquerque, New Mexico 87101

Solar Sustinance Project, Inc.
107AA Santa Fe
Santa Fe, New Mexico 87501

Sohio Petroleum Company
6001 Marble N.E.
Suite 15-26
Albuquerque, New Mexico 87102

Sun TEQ Engineering
2323 Los Padillas S.W.
Albuquerque, New Mexico 87101

The Solar Room Company, Inc.
Box 1377
Taos, New Mexico 87571

Zomeworks Corporation
1212 Edith N.E.
Albuquerque, New Mexico 87107

State Agency

Employment Security Commission
P. O. Box 1928
Albuquerque, New Mexico 87103

New Mexico Energy Research and Development Institute
New Mexico State University
Las Cruces, New Mexico 88003

Research Organizations

Los Alamos Scientific Laboratory
Los Alamos, New Mexico 87544

Sandia Laboratories
Albuquerque, New Mexico 87115

White Sands Missile Range
Las Cruces, New Mexico 88002

Waste Products

Arizona

City of Phoenix Sanitation Department
620 W. Washington
Phoenix, Arizona 85003

Henningson, Durham and Richardson
Suite 1222 - 100 W. Clarendon
Phoenix, Arizona 85013

Maricopa County Agricultural Extension Agent
Phoenix, Arizona 85001

Tricity Sewage Treatment Plant
215 E. McDowell Road
Phoenix, Arizona 85004

Boyle Engineering
3625 N. 16th Street, Suite 107
Phoenix, Arizona 85015

New Mexico

New Mexico State University
Biology Department, Room 305
Las Cruces, New Mexico 88003

Stahmann Farms
Las Cruces, New Mexico 88001

Wind

New Mexico

Extension Department
New Mexico State University
Las Cruces, New Mexico 88003

Sandia Laboratories
Albuquerque, New Mexico 87115

Other State Agencies

Arizona

Office of Planning and Development
1700 W. Washington, Room 507
Phoenix, Arizona 85003

New Mexico

Employment Security Commission of New Mexico
P. O. Box 1928
Albuquerque, New Mexico 87103

APPENDIX D

Lists of Perceived Existing and Emerging Policies

Responses to question 2: In New Mexico or Arizona, what energy policies related to manpower needs exist now?

Coal Gasification

Regulations on public land leases exist (Environmental)	2
Laws on strip mining exist	3
Federal controls on water usage	2

Geothermal Energy

Rules and regulations related to environmental protection exist	3
Federal loans for geothermal exploration and development are available	1
Training courses in geothermal and nuclear energy are offered at the University of New Mexico and the New Mexico Institute of Mines and Technology	1
Petroleum companies are blocking the development of geothermal energy	1
The New Mexico Energy Institute at New Mexico State University was created to conduct research on geothermal energy	1
Lack of interest in geothermal energy on the part of the utility companies is observable	1
Bureaucratic administrative rules and regulations slow down work in geothermal exploration	1
Leasing regulations are confusing	2
Arizona imposed a moratorium on state land leases: classification of resource as water or mineral	2

Nuclear

Minimum standards for manning of nuclear plants have been developed	1
Environmental concerns, especially about water, have slowed development	1

Nuclear referendums slow investment	1
Solar Energy	
Tax incentives in Arizona and New Mexico	12
Utility companies are the biggest blocks to wide use of solar energy	2
Current laws discriminate against solar energy installations	2
Minimum wage laws make labor too expensive	2
Government red tape if hire employees slows expansion	3
Government regulations: HUD	1
OSHA	1
Zoning restrictions	5
Unavailability of funding	1
Savings and loan companies can lend to solar energy developers if the developers are able to sell 70 percent of their products	1
Bank loans require back-up heating systems if solar is installed	1
The Federal government gives grants for solar energy development	1
The State of Arizona created Arizona Solar Energy Research Commission	3
The New Mexico Legislature passed The Solar Energy Development Act	1
The low natural gas price discourages more exertion of efforts in solar energy development	1
Interface with unions	1
General	
No adequate energy policies exist	9

Pertinent labor laws exist in the two states of Arizona and New Mexico	2
Pima County in Arizona issued various codes to encourage the use of alternative sources of energy	1
No tax relief exists for those who work on energy saving units	1
More government funds are granted to producers of conventional sources of energy	1
The big users of government grants are the utility companies and the research and development centers	1
No consistent policy supporting energy exploration exists	1
The existence of the Affirmative Action Act affects the activities of the energy industry	2
Large number of regulating agencies	1

Responses to question 3: With developing sources of energy, do you foresee new energy policies emerging?

Coal Gasification

Environmental regulations should not be made retroactive	1
Placing emphasis on state regulations regarding mining	2
Developing tax policies concerning removal of uranium and coal in New Mexico	2
Developing policies related to the potential utilization of slurry pipe line	1
Providing Federal subsidies	1

Geothermal Energy

Enacting more favorable tax relief laws as incentive for geothermal energy development	3
Explaining in simple terms the main concepts of geothermal energy and solar energy systems to common people	2

Developing more favorable land lease regulations	2
Streamlining the procedure for acquiring land leases	2
Developing depletion allowance policy	1
Providing grants and subsidies for promotion of geothermal energy	1
Developing well defined laws on private land leases	1
Nuclear	
Reprocessing and utilizing nuclear waste	2
Encouraging development of nuclear energy through Federal activities	1
Solar Energy	
Educating the general public on the utilization of solar energy	12
Issuing licenses based on defined standards	3
Standardizing of equipment, safety requirements	4
Updating building codes	1
Providing federally insured low interest loans for solar energy development	4
Providing more government (Federal, state) subsidies for solar energy utilization	4
Providing better tax incentives for investment in solar equipment	17
Providing monetary inducement (by Federal government) to purchasers of solar equipment for homes and pools	2
Providing easily obtainable financing for purchase of solar homes	6
Establishing a workable procedure for the cooperative development of solar energy by public and private sectors	3

Stimulating commercial use of solar energy	4
Placing emphasis on planning in the development of solar energy	2
Providing legislation which regulates access to sun	1
Developing new educational policies related to the training of plumbers, sheet metal installers, etc.	1
Offering a "retrofit" course for current plumbers	1
Offering a solar engineering course worth three credit hours for mechanical engineers	1
Building solar heated demonstration homes	1
Providing more Federal support to small operations	2
Setting prices on conventional fuels to cover actual cost of fuel	4
Setting rate structures on electricity according to cost	3
Pumping more Federal money into action programs in solar energy	2
Wind	
Providing incentive programs	1
Providing low interest loans	1
General	
Placing more emphasis on conservation and solar energy utilization by providing more tax incentives	12
Decontrolling natural gas prices and deregulating exploration and production of energy (of especial concern to respondents working in solar energy)	4

Easing bureaucratic procedures in order to facilitate the development of new favorable energy policies	2
Establishing energy policies that do not favor large power utilities	1
Approaching those with vested interests in conventional energy sources pragmatically	1
Pumping more Federal money into research and development streams of emerging energy sources	1
Developing policies related to fuel prices and the emerging energy industries	1
Extending bank credit to solar energy system installation and to innovative energy projects	1
Encouraging investment tax credit, accelerated depreciation on emerging energy sources, and removal of subsidies on conventional fuels	1
Modifying corporate tax to encourage big investment in emerging energy sources	1

APPENDIX E

Manpower Needs for Operation of Two Coal-Fired Generating Plants

There will be a large and continued demand for technicians and skilled craftsmen in the coal-fired generating plants situated in the Four-Corners area. More plants are being built in the area and some openings are expected to occur as the plants at the Palo Verde Station begin operation. It was pointed out by officials at the Salt River Project that, while coal has been used to fire electrical generating plants for many years, the new plants incorporate much advanced technology which does require new skills on the part of operators and maintenance technicians. Following are breakdowns of employees by job title for the Navajo Station, which is now in operation, and for the San Juan Station, which is under construction.

Since many of these plants are located on reservation lands, the projects are expected to hire Native Americans whenever possible. The companies interviewed have emphasized that these people need more technical training. It was also recommended that occupational training include the teaching of better work habits.

Simulators are being used more and more to train people to work in coal-fired plants. The success with reactor simulators has prompted utilities to put added emphasis on the training of fossil operators. Rittenhouse states that "complex environmental issues and related equipment" have added to "the current tremendous acceleration in new technology. The great size and complexity of the new fossil plants...are such that they can baffle even an experienced operator without advanced training" (1976, p. 39). The Salt River Project has a simulator for training operators at the Navajo Station and will also have a simulator at its Coronado Station.

Generally, more efforts are being directed towards training of employees in fossil-fired plants, not only in training operators, but also in training maintenance workers. A number of training materials are being produced for this purpose (Rittenhouse, 1976, p. 45).

Electronically Operated, Coal-Fired Generating Plant
Navajo Generating Station, Arizona

Job Title		Number
Superintendent		1
Assistant Superintendent		1
Secretary II		1
Clerical		13
		16
Operation	122	
Maintenance	288	
Railroad	86	
Engineering	59	
TOTAL	555	571
Operations		
Supervisor		1
Shift Supervisor		6
Assistant Shift Supervisor		15
Control Operator		15
Assistant Control Operator		15
Auxiliary Operator		20
Assistant Auxiliary Operator		10
Fuel Handler		20
Assistant Fuel Handler		10
Operator Trainee		10
TOTAL		122
Maintenance		
Supervisor		1
Assistant Supervisor		2
Maintenance Foreman		14
Machinist		10
Machinist Apprentice		4
Mechanic 1st class		36
Mechanic 2nd class		34
Mechanic, Auto		7
Mechanic, Auto Apprentice		2
Metal Fabricator		8
Welder		8
Metal Fabricator Apprentice		4
Painter		3
Trades Helper		30

Equipment Operator IV	8
Equipment Operator III	4
Truck Driver IV	6
Air Conditioner Mechanic 1st class	2
Serviceman, Equipment	2
Insulator	3
Truck Driver III	4
Utility Automan	2
Electrical Supervisor	1
Electricians	15
Electrician Apprentice	5
Relayman	2
Relayman Apprentice	2
Trade-helper	4
Electric Wkg. Foreman	3
Relay, Wkg. Foreman	1
Materials Planning Supervisor	1
Storekeeper	1
Scheduler	4
Warehouseman, Division A	1
Warehouseman, General	6
Warehouseman, Senior	2
Buyer	1
Expeditor	1
Warehouse, Records	1
Utility Foreman	3
Custodian	10
Labor, Plant Senior	30
Labor, Student	12
TOTAL	288

Engineering

Plant Engineer	1
Mechanical Engineer Leader	1
Mechanical Engineer, Senior	4
Mechanical Test Engineer, Senior	1
Engineering Technician	2
Environmental Engineer, Senior	1
Environmental Technician, Senior	5
Civil Engineer, Senior	1
Electrical Engineer Leader	1
Electrical Engineer, Senior	2
Electronic Technician, Senior	3
Chemical Supervisor	1
Fuel Analyst	2
Chemical Specialist	9
Computer Supervisor	1
Computer Engineer, Senior	1
Computer Technician, Senior	1

Instrument Supervisor	1
Instrument Technician	12
Instrument Mechanic	6
Instrument Foreman	3
TOTAL	59

Railroad

Supervisor, Equipment Maintenance	1
Maintenance Foreman	1
Mechanic 1st class	8
Mechanic 2nd class	9
Machinist	1
Warehouseman, Division A	1
Welder	2
Foreman, Electrical Wkg.	2
Electrician	7
Laborer	3
Track Maintenance Supervisor	1
Track Foreman	3
Engineer, Civil	1
Equipment Operator, IV	4
Equipment Operator, Mech.	1
Laborers, Senior	15
Serviceman, Equipment	1
Foreman, Track Wkg.	2
Road Foreman	1
Train Operator	9
Train Operator, Trainee	9
Dispatcher	4
TOTAL	86

Source: Salt River Power Project

San Juan Plant
Waterflow, New Mexico

Manning Levels for Technicians, Specialists, Analysts, Crafts, Operators, Planners, Inspectors, etc. at San Juan Plant:

Classification	1-1-77	1-1-81
Control Room Operators (Includes Operators in all grade levels)	42	71
Lab Analyst or Technician	15	38
Computer Technician	5	9
Chemical Technician	1	6
Engineering Technician	1	6
Process Technician	0	2
Maintenance Planner	1	7
Maintenance Inspector	1	2
Maintenance Parts Specialist	0	7
Draftsman	1	4
Mechanics (Includes Mechanics in all grade levels except unskilled helpers)	35	93
Electricians (Includes Electricians in all grade levels except unskilled helpers)	18	51
Instrumentation (Includes Instrumentation Maintenance people in all grade levels except unskilled helpers)	15	35
Control Board Operators, SO_2 Removal	0	8
Outside Plant Operators, SO_2 Removal	0	24
	93	282

Source: Public Service Company of New Mexico

Solar Energy Instructional Module

"Understanding Solar Energy Systems"

Laurie Keaton
Everett D. Edington

Educational Research Center
New Mexico State University
Las Cruces, New Mexico

This material was developed from a research grant with the Bureau of Occupational and Adult Education, Office of Education, U.S. Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgement in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

PROCEDURES FOLLOWED IN PREPARING THE INSTRUCTIONAL UNITS

In the late spring, 1977, the project staff summarized data, met with the advisory board, and discussed findings. A preliminary report of the findings was prepared. These activities provided the project staff with some perspective concerning the final phase of the project, which was to prepare several teaching modules. It had been concluded that there were certain training needs in the solar energy industry for which suitable teaching materials were not available. It had also been concluded that while a two-year solar technician program was not desirable, some teaching units emphasizing the importance of understanding solar energy systems would be useful. A number of employers in the solar energy industry had stressed the need for workers to understand the importance of treating a solar unit installed in a house for heating the interior, the domestic hot water, or a pool as a system. It had been suggested that workers in the solar industry needed to understand how the components of the system worked together.

It had been hoped that the information needed for preparing the instructional units would be available. Therefore, the first step taken was to contact the New Mexico Solar Energy Institute, the New Mexico Solar Energy Association, and the Arizona Solar Energy Commission. Through these contacts, it was learned that some efforts to develop solar energy programs were being made at two Texas Schools: Navarro College and Texas State Technical Institute.

Also, the staff learned about the short courses being offered at the University of Colorado at Fort Collins. It seemed that several groups were in the process of preparing curricular outlines. However, there appeared to

be no suitable texts to use. Also efforts and materials available or being prepared were aimed either at two-year solar technician programs or were for engineers.

The purpose of the units under consideration by this project was to inform the working plumber; carpenter; or heating, air conditioning and ventilation technician of some basic information about solar energy systems. It was also suggested that these materials be used to introduce instructors at technical schools to general concepts about solar energy systems in order to prepare them to teach a short course on solar energy systems in existing technical programs training other types of technicians. The idea was that in this way a technician could remain more generalized, but have an introduction to solar energy systems.

A consultant from the New Mexico Department of Education, Bill Jackson of the Vocational and Technical Division, met with the project staff. Some sample teaching units were provided as suggestions about format for the units. The New Mexico Vocational and Technical Education Division hope to use the units in state educational programs. The format suggested, and adopted for use in preparing the units, is standard for teaching units prepared by the state departments of education in Arizona, New Mexico, Colorado, and Oklahoma.

Jackson also made suggestions about procedures. These included interviewing employers in the solar industry and contacting labor union apprenticeship trainee supervisors.

In order to obtain more information about what materials were available on solar energy systems, a member of the project staff traveled to Arizona. The library at the Arizona Solar Energy Commission in Phoenix was made available,

and some useful materials were acquired there and at Arizona State University's solar energy collection, housed in Hayden Library.

While in Phoenix, the staff member discussed the probable content of the units with an employer who has been extremely active in the solar industry in Arizona. Also contacted was the area representative for a private solar equipment manufacturing firm which is in the process of preparing teaching materials on solar energy. However, these materials were not on the market at that time, and the price for the materials was beyond the resources of the project, so that had the materials been available they could not have been used by the project staff.

The next week, the staff member traveled to Albuquerque, New Mexico. Dr. Larry Bickle, President of an engineering consulting firm, provided an outline of what he conceived to be important topics to be included in the instructional units. Another employer in the Albuquerque area was also contacted for input about the units. The person in charge of apprenticeship programs for the carpenter's union in New Mexico was also contacted. He provided some materials which were used by the unions to inform their members about installation of solar energy systems for heating homes, domestic hot water, and pools. During the same period, some materials came to the attention of the project staff and were ordered.

The process of obtaining input from people in the industry, examining materials for use in the units, and assimilating the information obtained took longer than had been anticipated. However, a final list of objectives for the units was prepared late in October. The objectives grew out of and were intended to satisfy the needs of those persons contacted during the previous month and employers interviewed the previous year. The unit

objectives were sent to Mr. Jackson for his reaction. It had been decided that some instruction sheets would also have to be prepared. Most of the materials examined were lengthy, and some were more technical than was desired for the units as conceived by the staff. Preparation of the instruction sheets, unit tests, and activities proceeded through the end of December. It was fortunate that some materials prepared by the Department of Housing and Urban Development could be used as instruction sheets to go with the units, for the availability of this material facilitated the process considerably. In all, seven instructional units have been prepared, which can be used individually, in groups, or in sequence.

After the curriculum unit was complete it was reviewed by Bill Jackson of the New Mexico State Department of Education and Roger Lambert of the Wisconsin Vocational Studies Center. Their reviews are attached to this report.

EVALUATIONS OF SOLAR ENERGY MODULE

Evaluation No. 1

SOLAR ENERGY CURRICULUM

UNIT 1

1.1 It is unclear whether or not the specific objectives are aimed at what the student will know or how the instructor will measure the knowledge, i.e.,

Objective 1. Match terms vs. objectives 2-4, Distinguish, Name, Identify, etc.

The first could be reworded to a knowledge outcome by saying: associate correct definition with common terms used relating to solar energy.

There is no objective dealing with the major unit objective of why solar energy should be developed. Possibly objective 2 and 5 could be translated to explain why but it is unlikely that the student will do so without help.

1.2 Reading level is extremely high - if aimed at general public, more

1.3 terms need explanation and definitions. I.e., elliptical nature of earth's orbit, BTU's, 1353 watts per square meter, plane perpendicular.

1.6 Transparency 1.1 doesn't do anything to illustrate point. Test - no question on why solar energy should be developed. Would help if terms were presented in narrative.

UNIT II

2.1 Again it would seem desirable to have specific objectives deal more closely with what the student will know/learn than with how they will be tested.

I.e., objective 1 - will be able to define the terms Declination angle, Azimuth, Solar Noon, etc.

2.7 Transparencies need caption or explanation
and
2.9 Narrative is extremely brief considering the complexity of the material - Some: For example: might help to drive the point home. (Unit III beginning)

It's difficult to read and know what should be learned. Activities are good but difficult.

UNIT III

3.1 Same problem with objectives.

3.2 Good definitions

Transparency 3.1 good but could use more labels.

3.5 Term: Transport medium

3.6 Assignment is unclear - should say something to alert student to think beyond energy systems.

Narrative is brief. Could be more explanatory but it gets the job done.

UNIT IV

4.1 Objectives better but still somewhat confusing - Are objectives for teaching or students

4.3 Terms incident radiation, heat transfer medium.

Again, if an example were used to lead into technical material, it would help. I.e., collectors - automobile becomes warm inside when sitting in the sun on a cold day.

4.2 Caption for transparency would help.

Good use of subheadings.

4.13 Transparencies need labels and captions.

Unit is long. Might consider breaking into two or three units.

Text and activities are o.k.

UNIT V

5.1 Some concern about objectives.

5.3 and 5.4 Some subheadings would help.

UNIT VI

6.1 Objectives are teacher objectives.

6.3 Term thermal gradients

Would help if terms were identified in narrative as the reader comes to them.

UNIT VII

Extremely long unit - may want to separate into subunits - good content and reading - good diagrams.

Evaluation No. 2

SOLAR ENERGY CURRICULUM

UNIT I

Transparancies need to be larger.

1.14 Use "name" rather than "list."

UNIT II

2.3 Objective 3 should be "position" rather than "location."

Add objective 5 - complete activity sheet (This objective should be added to each one of the units)

UNIT IV

4.3 Make 3b separate objective (4) and renumber objectives.

4.9 List advantages and disadvantages of open water collector (do same after hot liquid and hot air in their respective sections.)

4.12 to 4.28 Change numbering sequence to match to objectives.

UNIT VII

Make sub-objectives major objectives and renumber activities accordingly.

List advantages and disadvantages of each type in chapter.

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Preface to
Solar Energy Instructional Module
"Understanding Solar Energy Systems"

In 1977 a research project was undertaken to determine manpower needs in emerging energy fields in Arizona and New Mexico. It was found that one of the fields with the greatest growth potential was in solar energy. While there is not a need for "new occupations" in the solar energy industry, there is a real need for those persons in existing skill areas to be trained to have a basic understanding of solar energy systems. This need cuts across all types of occupations from sales to assembly to installation.

This instructional package is to help meet this need. It is designed for programs of post high school technical education and adult education programs. It could be used in both pre-service and in-service situations. It is not designed to provide the technical skills necessary for installation of solar energy systems but to provide a basic understanding of such systems.

Laurie Keaton
Everett D. Edington

Acknowledgments

Special appreciation is extended to Bill Jackson of the New Mexico State Department of Education and to Roger Lambert of the Wisconsin Vocational Studies Center for their evaluations of the instructional module.

It would also have been impossible to complete the project without the assistance of Dr. Larry Bickle of L. W. Bickle and Associates and the members of the advisory council for their continued support of the project.

Table of Contents

Preface i

Acknowledgments ii

Unit I Using Solar Energy 1.1

Unit II Locating the Sun 2.1

Unit III Solar Energy Systems 3.1

Unit IV Collection 4.1

Unit V Storage 5.1

Unit VI Distribution 6.1

Unit VII Representative Solar Energy Systems for Heating Homes 7.1

Glossary 8.1

UNIT I

USING SOLAR ENERGY

UNIT OBJECTIVE

After completion of this unit, the participant should be able to explain why solar energy should be developed as an energy source and describe some characteristics of solar radiation. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit the student should be able to

1. Match terms relating to solar energy with the correct definitions.
2. Distinguish between renewable and nonrenewable energy sources.
3. Name some uses of solar energy.
4. Identify correct statements about solar radiation.
5. Identify accurate statements about problems associated with using solar energy.

1. Terms and Definitions

Energy-the ability to do work.

Nonrenewable energy source-a substance found in nature which cannot be replenished and which can be used to obtain energy in some form. Coal, gas, uranium are examples of nonrenewable energy sources.

Renewable energy source-a substance which occurs in nature and the supply of which cannot be depleted by use.

Photovoltaic-direct conversion of the sun's energy to electricity.

Biomass conversion-energy from the sun is stored through the process of photosynthesis in plants, i.e., in organic material. Chemical processes can be used to change the organic material to simpler forms with an accompanying release of energy.

Radiation-any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Solar constant-the amount of solar energy striking the outer atmosphere of the earth varies only slightly and can be treated as a constant.

Insolation-the amount of solar radiation actually striking the surface of the earth.

Direct radiation-direct or parallel rays from the sun.

Diffuse radiation-the solar radiation striking the surface of the earth after its direction has been changed by reflection and scattered by particles in the atmosphere--nondirectional rays.

2. Importance of Solar Energy

The oil embargo of 1973 brought to the attention of the American people how dependent the United States has become on imported oil. Since that time, efforts have been made to assess the nation's energy needs and supplies. With this focus on the question of the availability of energy resources in this country has come an increased interest in solar energy.

Those energy sources now used--coal, gas, and uranium--are available only in fixed quantities. When that quantity is used up, there will be no more. For this reason, these are called nonrenewable energy sources. These energy sources present problems not only because they are nonrenewable energy sources but also because they create problems. The burning of fossil fuels pollutes the atmosphere. The waste from nuclear-fired power plants presents hazards. All contribute to the thermal pollution of our environment.

On the other hand, solar energy is a renewable resource. In using the sun's energy, man will not exhaust the supply. Not only is solar energy plentiful, but also its use does not create pollution problems. The sun is the source of almost all of the earth's energy.

3. Applications of Solar Energy

Man has made use of energy obtained from the sun for thousands of years, expecially to heat water and to dry food materials. Wind energy and geothermal energy are forms of solar energy. Both are used today for a number of purposes. Other applications of energy obtained directly from the sun include the generation of electricity through solar-thermal applications or photovoltaic cells. Also, synthetic fuels can be obtained from solar energy in biomass conversions to methanol or indirect combustion of cellulose.

The application of solar energy considered here will be for heating and cooling buildings, heating of domestic hot water, and heating of water for swimming pools.

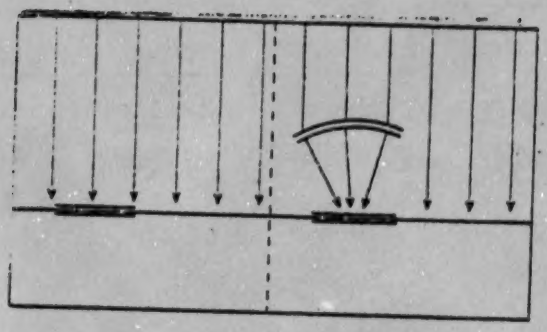
4. Solar Radiation

Energy is transmitted from the sun to the earth by radiation. Solar radiation is transmitted from the sun in wavelengths, of which visible light represents only a small portion. The intensity of the radiation reaching the upper surface of the earth varies slightly because the sun's output varies. Also, the distance between the sun and earth varies owing to the elliptical nature of the earth's orbit about the sun.

These variations are considered to be so minor that the amount of solar radiation reaching the outer atmosphere is treated as a constant. The solar constant equals very nearly 429.2 Btu's per square foot per hour, or 1,353 watts per square meter. It is the intensity of solar radiation striking a plane perpendicular to the sun's rays at a distance equalling the average distance of the surface of the earth's outer atmosphere from the sun (see Transparency 1.1)

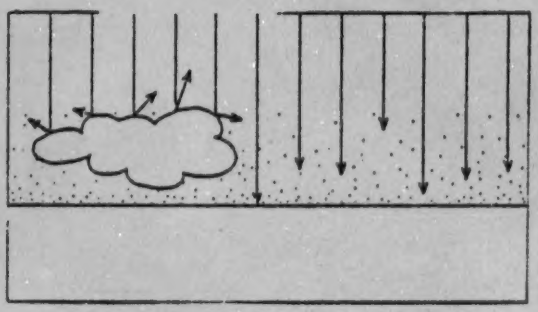
Although the amount of solar radiation striking the earth's outer atmosphere is relatively constant, not all of that energy actually arrives at the surface of the earth. Almost one-half of the energy either is reflected by particles in the atmosphere back into space or is absorbed by material in the earth's atmosphere (see Transparency 1.2)

Insolation is the amount of solar radiation which actually strikes the earth. Insolation, the solar radiation actually reaching the earth, is of three types: direct radiation or parallel rays, diffuse radiation or nondirectional rays, and rays reflected from the ground or from building surfaces (see Transparency 1.3)



Transparency 1.1: SOLAR CONSTANT

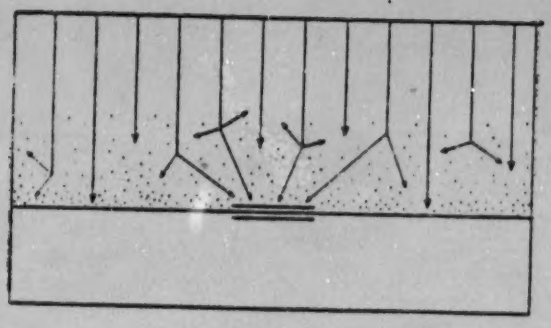
There is a nearly constant amount of solar energy striking the outer atmosphere--429 BTU per square feet per hour and this quantity is know as the solar constant



Transparency 1.2: ABSORPTION AND REFLECTION

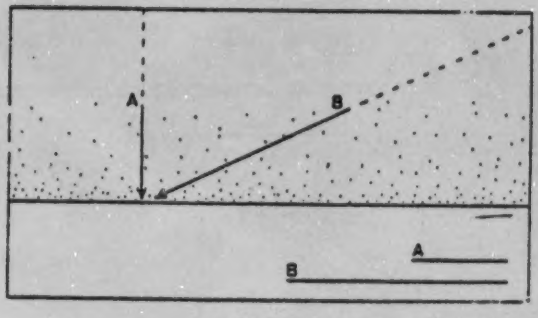
Nearly half the solar radiation entering the earth's atmosphere is lost through absorption by material in the atmosphere, or by reflection from clouds.

Source: AIA Research Corporation, Solar Dwelling Design Concepts. Developed for the U. S. Department of Housing and Urban Development. May 1976.



Transparency 1.3: DIFFUSE RADIATION

Clouds and particles in the atmosphere not only reflect and absorb solar energy, but scatter it in all directions. Because of this, solar energy is received from all parts of the sky-more so on hazy days than on clear days. Such radiation is called diffuse, as opposed to the normal direct radiation.



Transparency 1.4: LENGTH OF TRAVEL THROUGH THE ATMOSPHERE

More solar radiation is lost by absorption at low sun angles because the length of travel through the atmosphere is greatly increased (that is why you can look directly at the sun at sunset). High altitudes have more solar radiation for the same reason.

The amount of insolation available at any given point on the earth's surface is affected by the purity of the earth's atmosphere, by the distance the radiation must travel through the atmosphere, and by the angle at which the solar radiation strikes the earth's surface. As the radiation travels through the earth's atmosphere, energy is absorbed by particles in the atmosphere. How much is absorbed depends on the amount of vapor, dust particles, or other matter present in the atmosphere.

Not only do the vapor and dust particles absorb energy, but also, these particles will reflect or deflect some of the sun's rays. Thus some of the solar radiation is lost when the solar rays are reflected back into space. Other of the rays become diffuse, or nondirectional. How many rays become diffuse or are reflected depends upon the purity of the atmosphere.

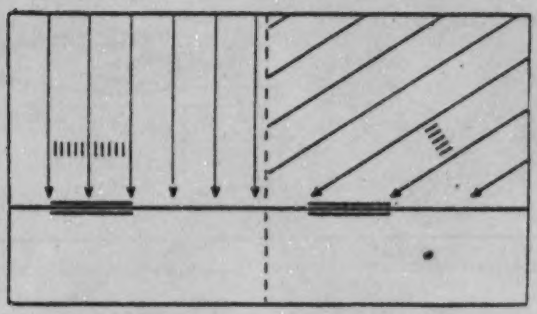
The distance the solar radiation must travel through the earth's atmosphere affects the amount of insolation available. The distance traveled affects how much radiation will be lost through absorption and reflection. It also affects how much diffusion of the solar rays will occur.

How far the rays must travel through the atmosphere is determined by the season of year and time of day. If the sun is low in the sky (close to the horizon), the radiation must travel a greater distance through the atmosphere before striking the surface of the earth (Transparency 1.4).

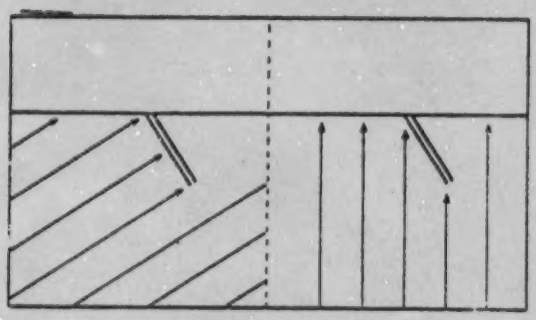
Also, radiation is most effective if the rays strike a surface perpendicular, or normal, to the direction the rays are traveling.

Therefore, direct or parallel rays are of greater energy value than are diffuse or nondirectional rays. Transparencies 1.5 and 1.6 give a visual representation of the importance of the tilt of the receiving surface.

The length of time radiation strikes a surface must also be considered when discussing the amount of insolation available at any given point on the surface of the earth. This fact again indicates that the angle at which radiation is striking the earth and the season of year are of great importance. These factors affect how much insolation is available for use as an energy source.



Transparency 1.5: COSINE LAW-HORIZONTAL SURFACE
Less solar radiation strikes a given horizontal area as the sun gets lower in the sky. The amount changes by the cosine of the angle, measured from directly overhead.



Transparency 1.6: COSINE LAW-TILTED SURFACE

The same law applies to a tilted surface, such as a solar collector. By tilting the collector so that it is more nearly perpendicular to the sun, more energy strikes its surface.

5. Problems in Using Solar Energy

Solar radiation is sufficiently dilute so that large surfaces are needed to collect the available energy. For example, in Albuquerque, one square meter, approximately 3' x 3', will supply only two percent of the heating needs for an average house. On the other hand, the total solar energy striking the roof and south wall is five to ten times more energy than is used in an average house for all purposes.

Solar energy is intermittent. Energy arrives only during the daylight hours. During periods of cloudy weather or winter storms, more energy may be lost than gained. For this reason, storage or auxiliary heating systems are essential.

At present, solar energy systems are best suited to low temperature applications. Some work is being done to develop solar furnaces which concentrate solar radiation to obtain extreme high temperatures. For use in dwellings, however, a low temperature technology is most suitable at present.

ASSIGNMENT SHEET

1. Explain why we can talk about the "solar constant."

2. Tell why only about one-half of the solar radiation which strikes the earth's atmosphere actually arrives at the surface of the earth.

3. Explain why the distance the radiation must travel through the earth's atmosphere affects the amount of solar energy available at a particular spot on the earth.

4. Name two problems involved in making use of solar energy.

UNIT TEST--USING SOLAR ENERGY

1. Match definitions to terms

___a. Energy

___b. Nonrenewable energy source

___c. Photovoltaic

___d. Radiation

___e. Direct radiation

___f. Diffuse radiation

___g. Insolation

___h. Solar Constant

___i. Renewable energy source

___j. Biomass conversion

1. Direct conversion of solar radiation to electricity.
2. Solar energy striking the outer atmosphere of the earth varies only slightly
3. Solar energy stored in organic materials is released through chemical processes.
4. Ability to do work
5. Transmission of heat waves from a warmer to a cooler surface.
6. The solar energy reaching the surface of the earth.
7. Use of the resource to obtain energy will lead to depletion of the resource.
8. Sun's rays are reflected and scattered by particles in the atmosphere
9. Naturally occurring source of energy which cannot be depleted.
10. Parallel rays from the sun.

2. Indicate with an N those energy sources listed below which are nonrenewable. Mark with an R any renewable energy sources included in the list.

___a. Coal

___b. Uranium

___c. Wind

___d. Gas

___e. Sun

3. List three applications of solar energy.

1. _____

2. _____

3. _____

4. Mark with a "T" the following statements about solar radiation which are true. Mark false statements with an "F".

___1. All solar radiation which strikes the surface of the earth is direct radiation.

___2. The intensity of the radiation reaching the upper surface of the earth's atmosphere does not vary.

___3. The intensity of the radiation reaching the upper surface of the earth's atmosphere varies slightly because the sun's output varies and because of the elliptical nature of the earth's orbit around the sun.

___4. The solar constant is computed as an average.

___5. Very little of the solar radiation striking the surface of the earth's atmosphere is lost by reflection or absorption.

___6. As solar radiation travels through the earth's atmosphere the rays become more direct.

___7. Radiation is most effective if the rays strike a parallel surface.

___8. The greater the distance the solar radiation must travel through the atmosphere, the greater will be the loss of energy through absorption and reflection.

5. Mark the following statements with a "T" if the statement is true, or with an "F" if the statement is false.

___1. The amount of solar energy available can be calculated.

___2. Large surfaces are needed to collect the available solar energy.

___3. The amount of solar energy striking the roof and south wall of an average house is less than the amount of energy normally used by the average household.

___4. Storage or auxiliary heating systems are needed because solar energy is not always available for collection.

ANSWERS TO ASSIGNMENT SHEETS AND UNIT I TEST

Answers To Assignment 1

1. The solar energy, which is transmitted to the earth, strikes the surface of the earth's atmosphere at a relatively constant rate. There is a slight variation only as the sun's output of energy varies. There is also some variation in the amount of energy received because the distance between the sun and earth varies owing to the elliptical nature of the earth's orbit. However, these variations are considered so minor that the amount of radiation striking the earth's outer atmosphere can be thought of as a constant and is call the "solar constant".

Answers To Assignment 2

The amount of solar radiation actually striking the surface of the earth is far less than the amount striking the surface of the earth's outer atmosphere because large amounts of the solar radiation are absorbed by particles in the atmosphere. Also, large amounts of radiation are reflected back into space by clouds or materials in the atmosphere.

Answers To Assignment 3

As solar radiation travels through the earth's atmosphere, more radiation is absorbed and more rays become diffuse.

Answer To Assignment 4

Problems associated with the use of solar energy are (1) that solar energy is a dilute source of energy, thus requiring large surface areas to collect the energy and (2) that solar energy is intermittent, thus requiring storage and even auxiliary heating systems.

Answers To Unit Test 1

a. 4

b. 7

c. 1

d. 5

e. 10

f. 8

g. 6

h. 2

i. 9

j. 3

Answers To Unit Test 2

a. N

b. N

c. R

d. N

e. R

Answers To Unit Test 3 (name three)

1. To dry food
2. To heat water
3. To heat buildings
4. Generation of electricity
5. To obtain synthetic fuels through biomass conversions
6. To cool buildings

Answers To Unit Test 4

1. F
2. F
3. T
4. T
5. F
6. F
7. T
8. T

Answers To Unit Test 5

1. T
2. T
3. F
4. T

References

AIA Resource Corporation. May 1976. Solar Dwelling Design Concepts. Prepared for the United States Department of Housing and Urban Development, Office of Policy Development and Research. Washington, D.C.: U.S. Government Printing Office.

Solar Energy Utilization for Heating and Cooling. 1974. Compiled by John I. Yellott for the American Society of Heating, Refrigerating and Air Conditioning Engineers. Washington, D.C.: U.S. Government Printing Office. Reprinted from Chapter 59 of the 1974 Edition, Applications Volume, of the ASHRAE Guide and Data Book series.

UNIT II

LOCATING THE SUN

UNIT OBJECTIVE

After completion of this unit, the participant will be able to explain the importance of the position of the sun in relation to the earth for making use of the sun's energy. This knowledge will be evidenced through demonstration and by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit, the student should be able to

1. Match terms with their correct definitions.
2. Identify correct statements about solar radiation and the importance of the earth's location with respect to the sun.
3. Complete sentences referring to the sun's location in the sky.
4. Identify true statements explaining why it is important to know the location of the sun.

1. Terms and Definitions

Azimuth-an angle obtained by measuring from due south and rotating until facing the sun.

Declination angle-the angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun.

Solar noon-that time of day when the azimuth angle is 0°, when the sun is due south of an observer.

Latitude-the angular distance north or south from the earth's equator measured through 90°.

Solar altitude-the angle of elevation of the sun above the horizon.

Irradiation-exposure to radiant energy.

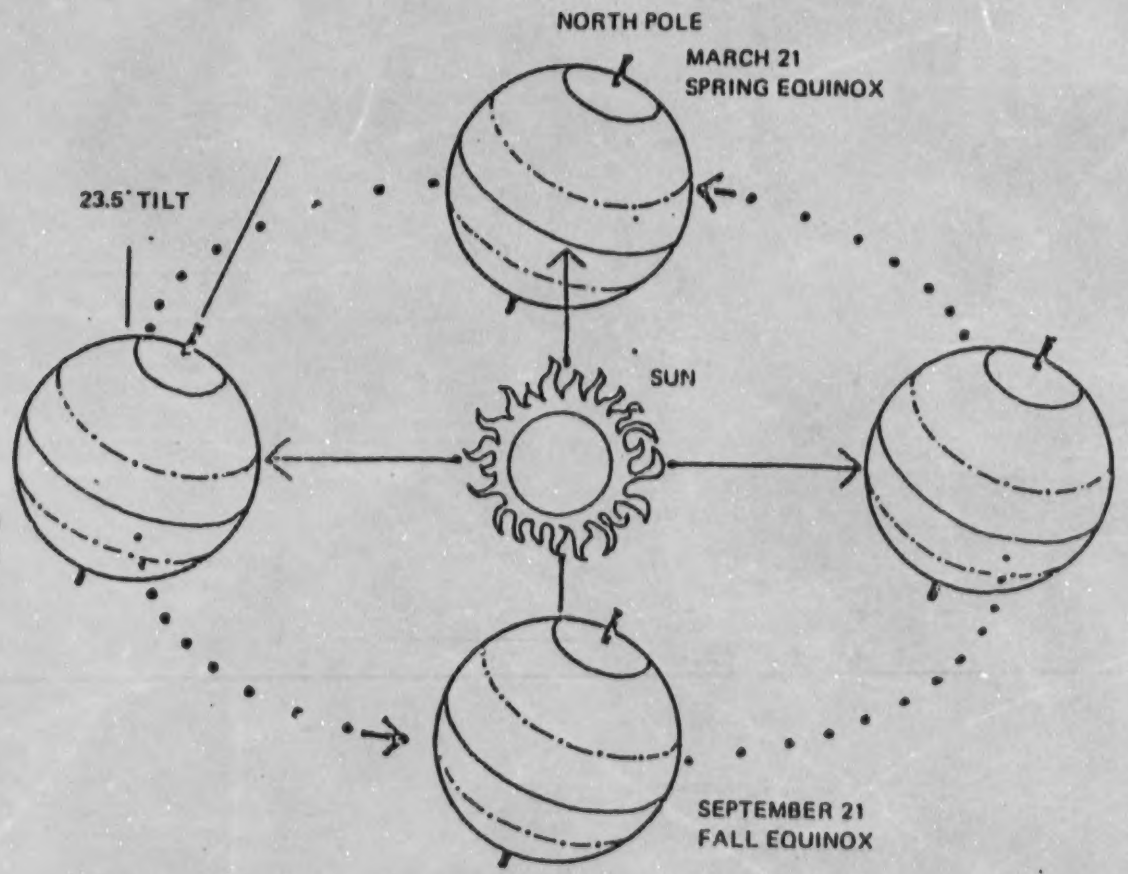
INFORMATION SHEET: LOCATING THE SUN

2. The Earth's Tilt

As the earth follows its elliptical path around the sun, it also rotates around its own axis. This axis can be defined as a line drawn through the north and south poles. The earth rotates once around its own axis every 24 hours--one day--and once around the sun every 365.25 days--one year.

The axis of the earth's rotation is tilted at an angle of 23.5°. This angle is calculated relative to the plane of the earth's orbit around the sun. The direction of tilt of the axis is constant, even as the earth rotates about its own axis and as it travels around the sun (see Transparency 2.1). The constant angle of tilt means that the spot on the earth's surface receiving the greatest amount of solar radiation varies. The greatest amount of radiation is received at the point on a surface most completely perpendicular to the sun's rays (see Transparencies I.5 and I.6 in Unit I). Relative to the equator, the spot moves north and south between the Tropic of Cancer (latitude 23.5° north) and the Tropic of Capricorn (latitude 23.5° south). What the sun "sees" is diagrammed in Transparency 2.2.

As the earth orbits about the sun, the tilt of the earth's axis causes the angle between the direct earth-sun line and the equatorial plane to change. This angle, called the angle of declination (Transparency 2.3), changes continually, according to date. The change in declination determines how much sunlight



2.4

Transparency 2.1

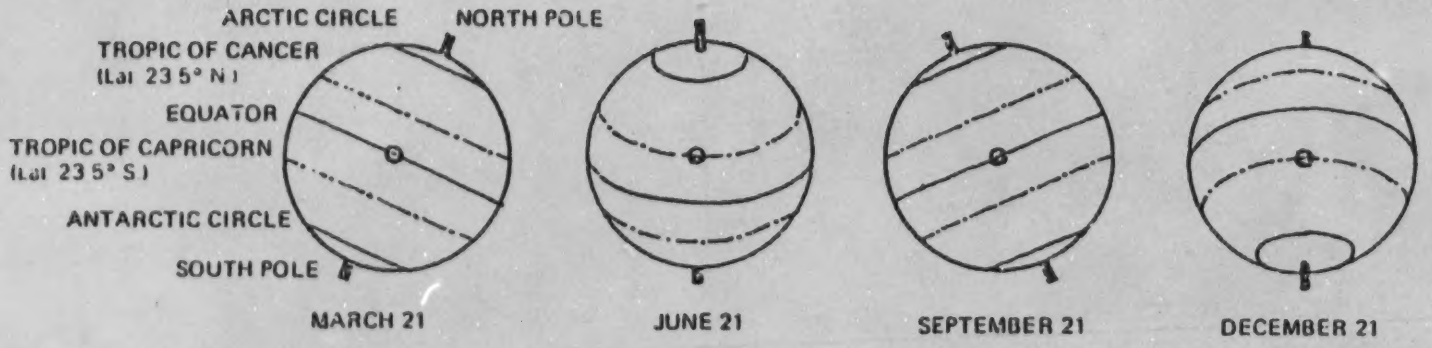
160

DIAGRAM OF THE EARTH'S PATH

The earth tilts 23.5° relative to the plane of its orbit around the sun. Solstices and equinoxes shown are for the northern hemisphere.

Source: AIA Resource Corporation, Solar Dwelling Design Concepts Developed for the U.S. Department of Housing and Urban Development. Washington D. C. : U.S. Gov. Printing Office, May 1976.

160-A



2.5

Transparency 2.2

WHAT THE SUN 'SEES'

The o shows the latitude at which the sun would be directly overhead

Source: AIA Research Coporation.
Solar Dwelling Design Concepts. Developed for the U.S Department of Housing and Urban Development.
Washington D. C.: U. S. Gov. Printing Office, May 1976

will strike a surface. Thus the change in declination explains variations in how intense is the amount of solar radiation at different places over the surface of the earth. It also explains variations in the length of daylight and darkness and changes of temperature at different times of year.

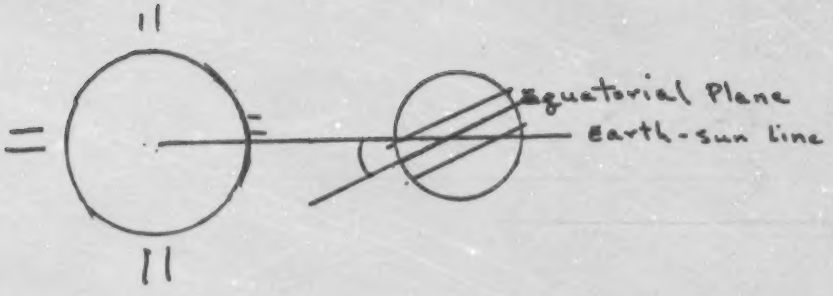
3. The Sun's Position In The Sky

The solar azimuth (see transparency 2.4) is an angle obtained by measuring from due south and rotating until facing the sun. The azimuth is defined to be 0° at solar noon. By knowing the solar azimuth and the solar altitude, one can state the position of the sun for any latitude at various times of the day. With this information, insolation values for a given latitude can be obtained. Tables giving the altitude and azimuth angles at different latitudes and for different hours of the day are available in the ASHRAE Handbook of Fundamentals (1972). Also, a Libby-Owens-Ford Sun Angle Calculator is available which calculates these angles for different times of day, for different days of the year, and at different latitudes.

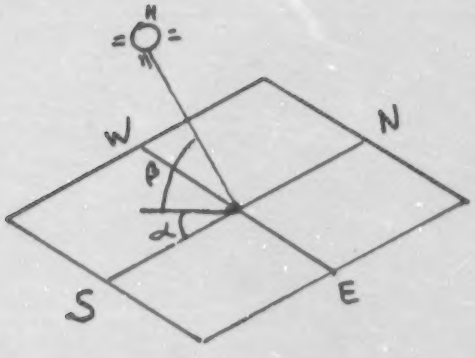
4. The Importance of Locating the Sun

Knowledge of the solar azimuth angle and the solar altitude angle, i.e., knowing where the sun will be at a specific time on a particular day, can help in planning a solar dwelling. By knowing the location of the sun at critical times, one can determine when house surfaces will be shaded during each season of the year and the intensity of solar radiation available.

For example, during the summer months, the sun may spend a substantial portion of the day to the north of an observer in the

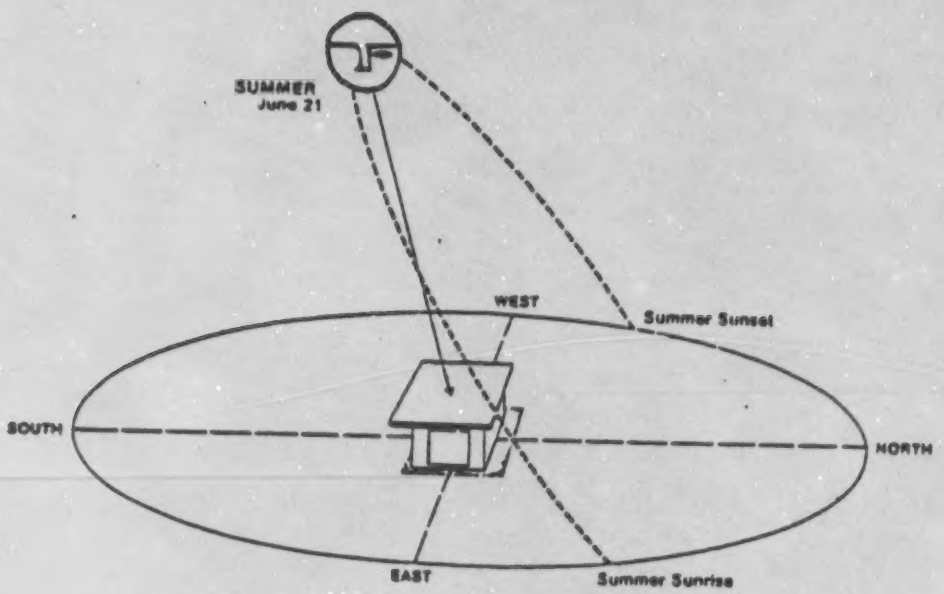


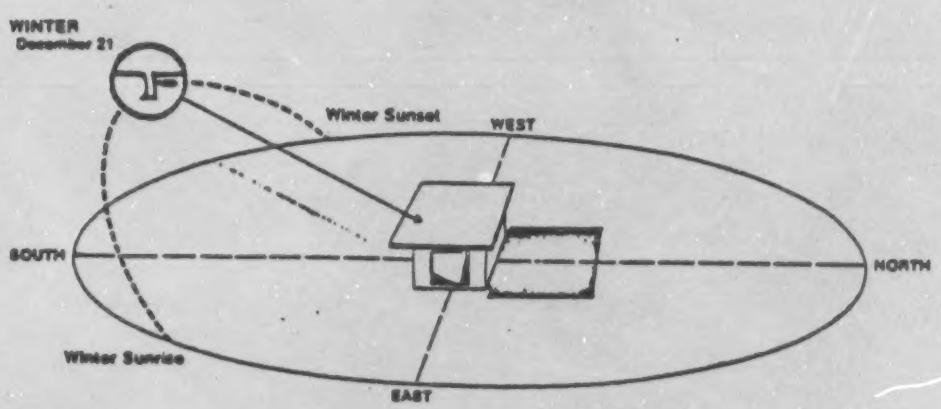
Transparency 2.3 Angle of Declination



Transparency 2.4 Solar Azimuth (α) and Solar Altitude (β)

northern hemisphere (see Transparency 2.5). Because the sun moves farther north in the summer, south-facing windows can be shaded by an overhang during the heat of the summer day. In this way, solar radiation is prevented from striking and warming the interior





Transparency 2.5

surfaces of a dwelling. Yet during the winter months, because the sun has moved farther south, a properly designed overhang will not shade the south-facing windows. This means the direct rays of the sun can be used as a source of energy for warming a dwelling in winter but still not add to summer cooling problems.

In Sunspots (1975), Steve Baer suggests a simple method for illustrating how much surface will be exposed to the sunlight at a specific time. Simply place a rod so that it extends perpendicularly from the flat surface of a board. Then read the shadows cast by the rod onto the board to determine how well the plane is oriented with respect to the sun. In this way one can visualize what orientation of a surface will affect the amount of exposure to the sun. Goodness or badness of orientation depends on the amount of irradiation desired on a specific surface.

The position of the sun is also important in determining how to place collectors to absorb an optimum amount of solar energy. A surface placed perpendicular to the direct rays of the sun will absorb the greatest amount of energy from the sun. Thus, depending upon the intended use of the energy collected, one may wish to tilt a solar collector so that it receives direct rays from the sun at one time of year and not at another.

ACTIVITIES--LOCATION OF SUN

Activity 1

A. Materials Needed

1. Protractor
2. Paper
3. Pencil
4. Model of house, showing overhang, drawn to scale.
5. Window cutouts, to scale: 3', 4', 5', 6' high.
6. Table showing solar position for X° Latitude on June 21 and on December 21.

B. Procedure

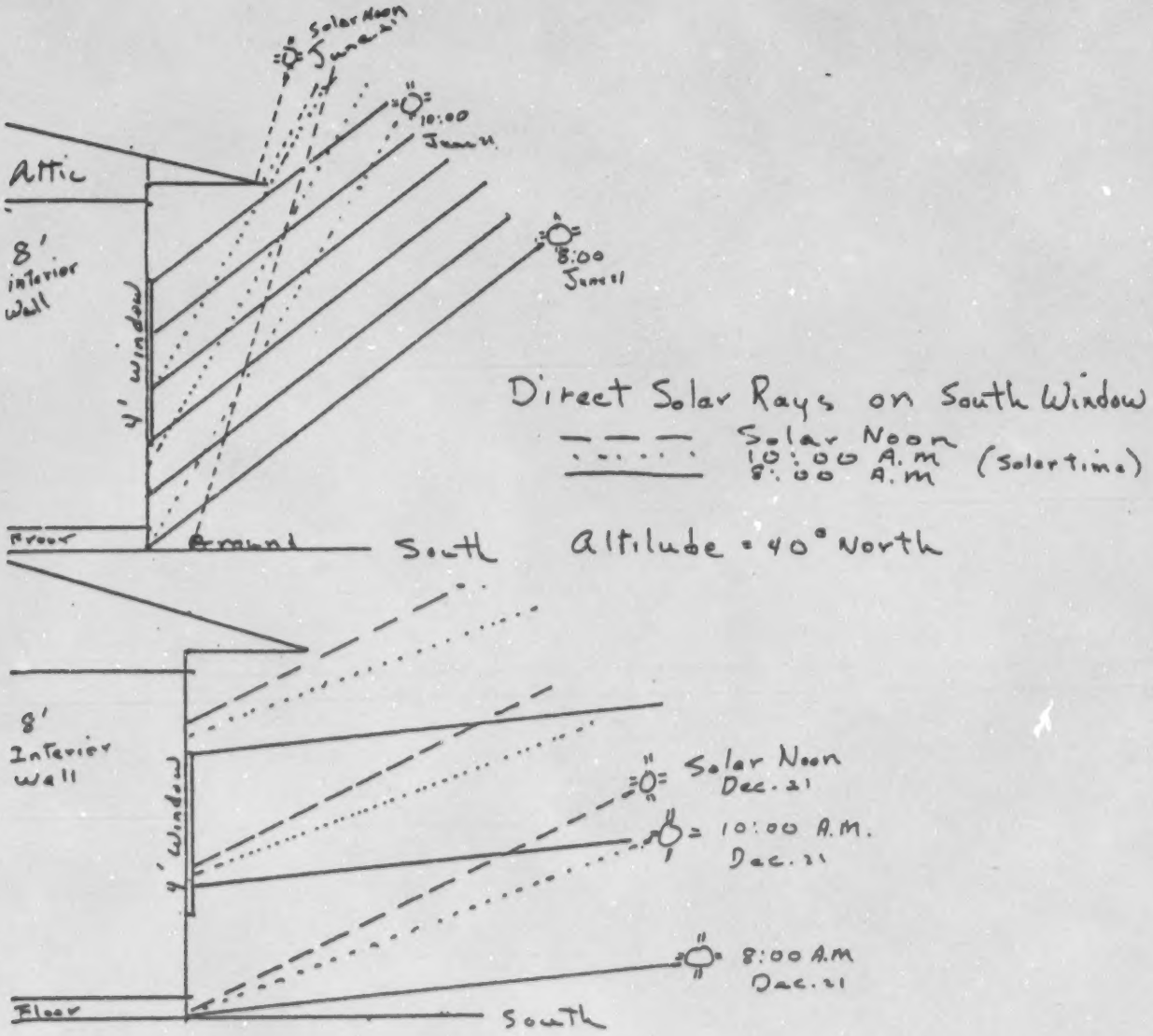
1. Set protractor so that side of house is at center (90°) of protractor and so that bottom of protractor is at ground level.
2. Reading from table, mark altitude angle at 8:00 a.m. on June 21.
3. Using broken line for angle at 8:00 a.m., draw parallel lines to side of house, maintaining the same altitude angle. Observe where the overhang stops the line, see example in Transparency 2.6.
4. Repeat "2" and "3" for altitude angles at 10:00 a.m. and solar noon on June 21. Use a dotted line for 10:00 a.m. and a solid line for solar noon.
5. Using a second model, follow the same steps for December 21.
6. Place window cutouts on side of house to determine placement for optimum shading.

C. What Has Been Learned?

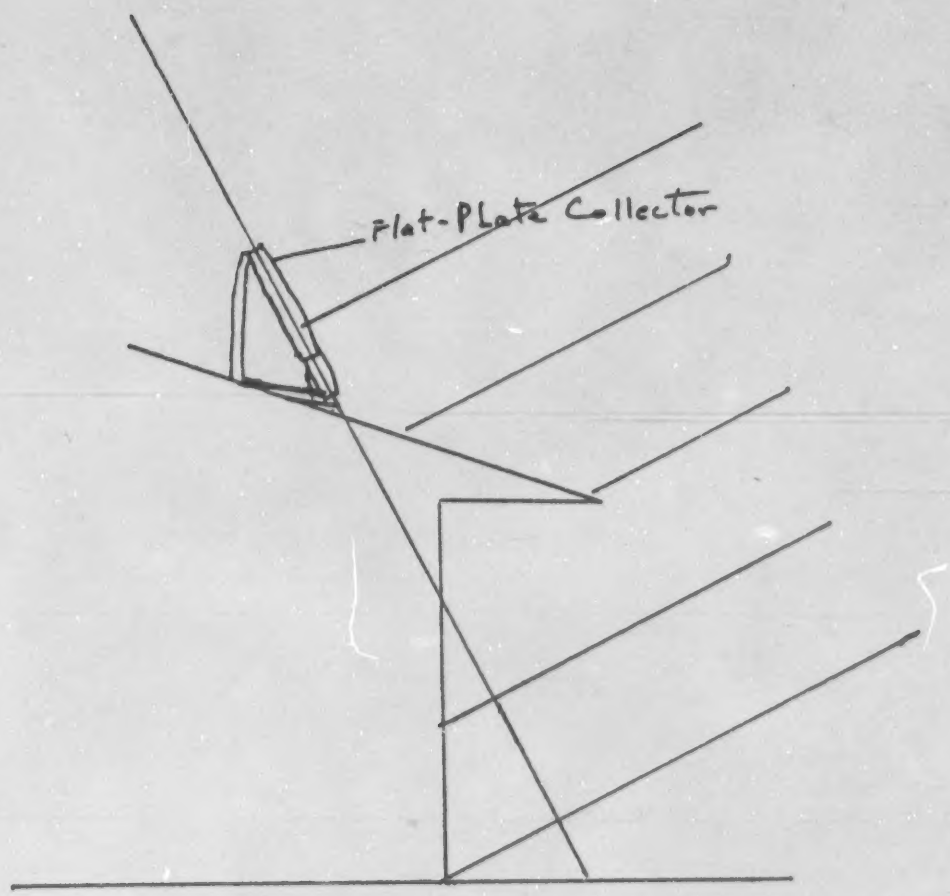
1. What is the effect of the overhang in shading a south-facing window?
2. What could be done in summer to avoid overheating?
3. What can be achieved by a smaller window, placed higher in the wall? Would this interfere with collection of solar radiation in winter? Why?
4. Where will the sun be at 2:00 p.m. on each day?

5. This activity takes only solar altitude into consideration. How does the azimuth angle effect where the sun will be?

6. How could the optimum angle for a flat-plate collector situated on the roof of your building be determined? See Transparency 2.7.



Transparency 2.6



Direct rays at Solar Noon on December 21.
Determing collector Tilt.
Transparency 2.7

Activity 2

A. Materials Needed

1. Protractor

2. Paper

3. Pencil

4. Table showing solar position for X° latitude on June 21 and on December 21.

B. Procedure

1. Establish north-south and east-west lines on a piece of paper.

2. With the protractor, mark off the azimuth angles, using due south as 0° and counting the degrees east or west from that point, for various times of day. Use a table for the latitude at which you live (see Transparency 2.8).

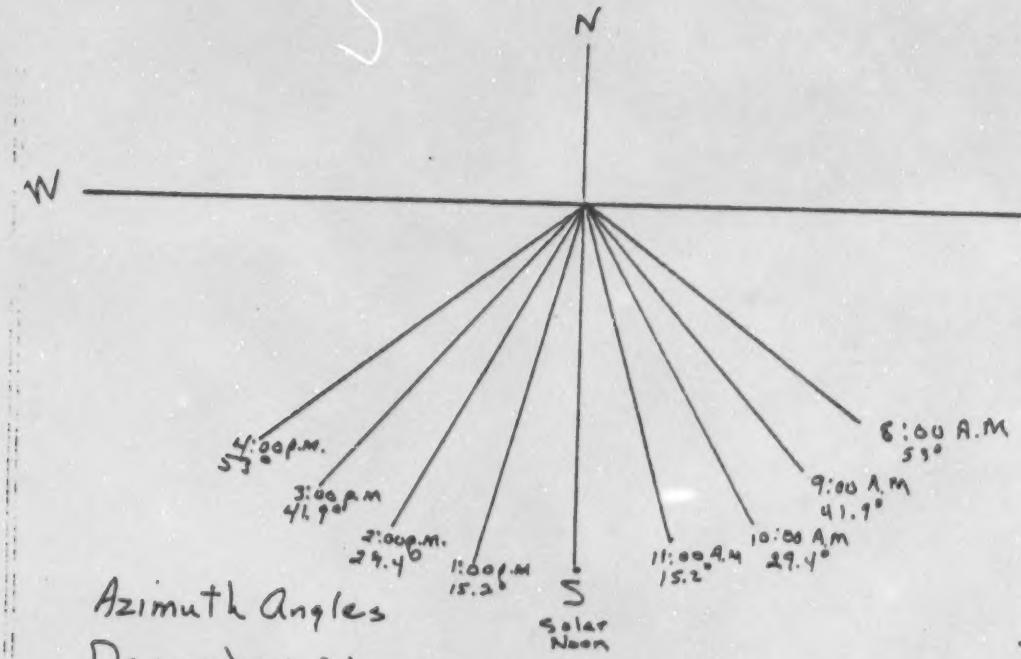
3. Mark off the azimuth angles for June 21, March 21, and December 21.

C. What Has Been Learned?.

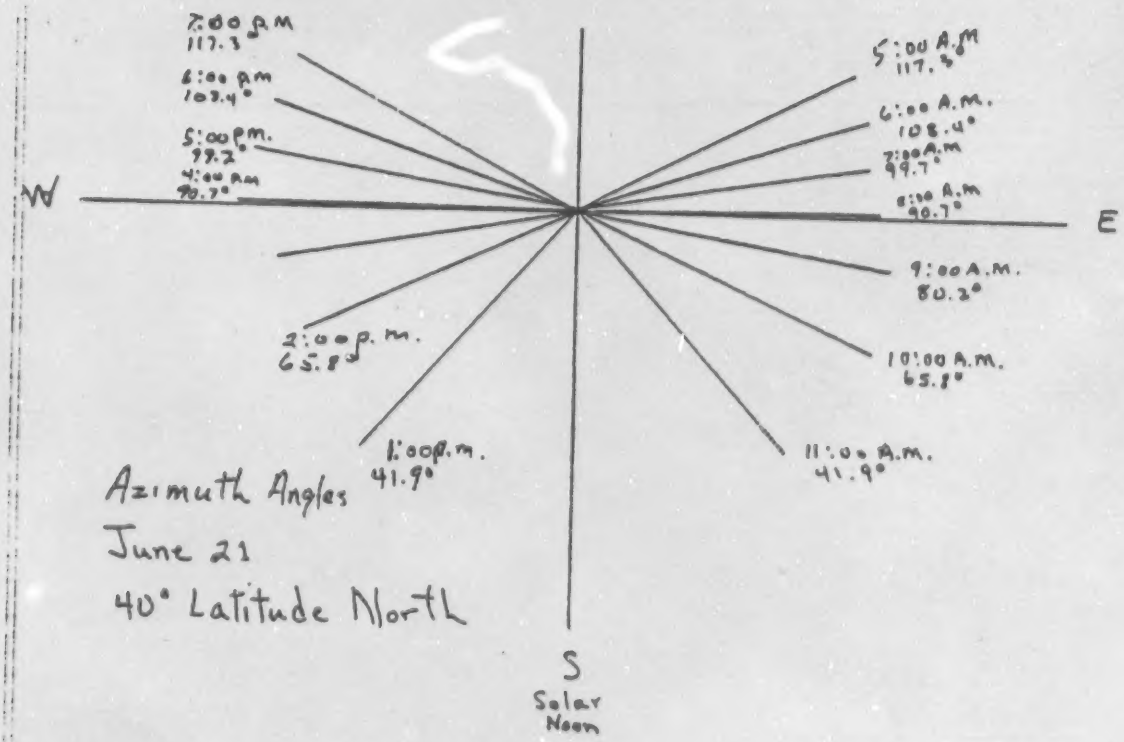
1. How does the angle at which direct solar radiation strikes a surface affect the amount of radiation available?

2. How does the above question bear upon the solar azimuth?

3. If the altitude and azimuth points for a given date could be plotted on a three-dimensional graph, the resulting line would represent the sun's path across the sky on that date. Transparency 2.9 represents the sun's path on December 21, March and September 21, and June 21. How do these drawings relate to the angles you have plotted for altitude and azimuth?

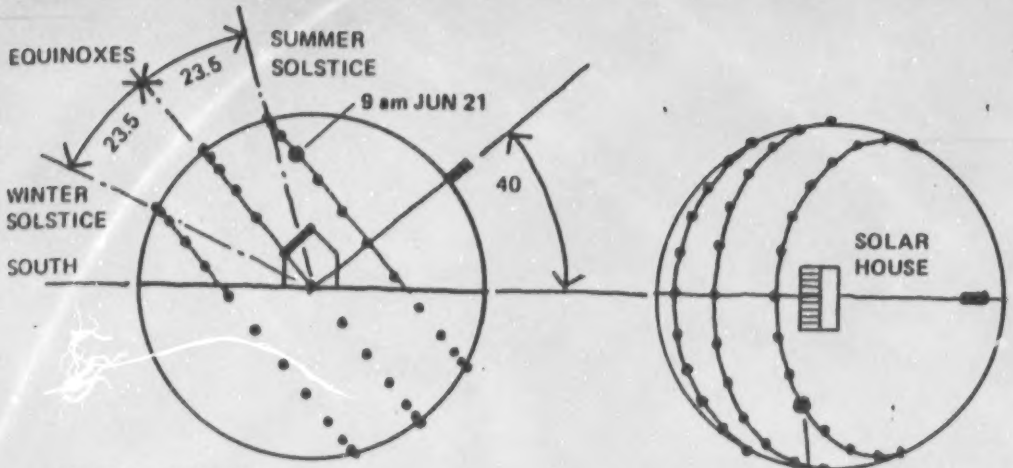


Azimuth Angles
December 21
40° Latitude North



Azimuth Angles
June 21
40° Latitude North

Transparency 2.8

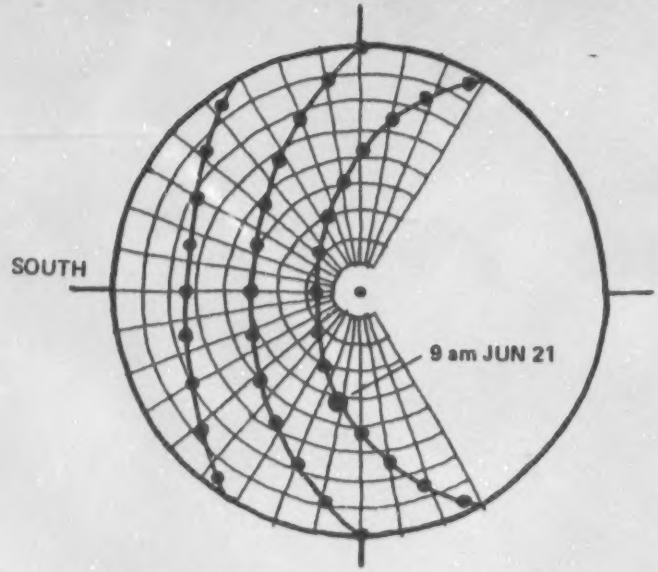


VIEW FROM EAST

9 am JUN 21

PLAN VIEW

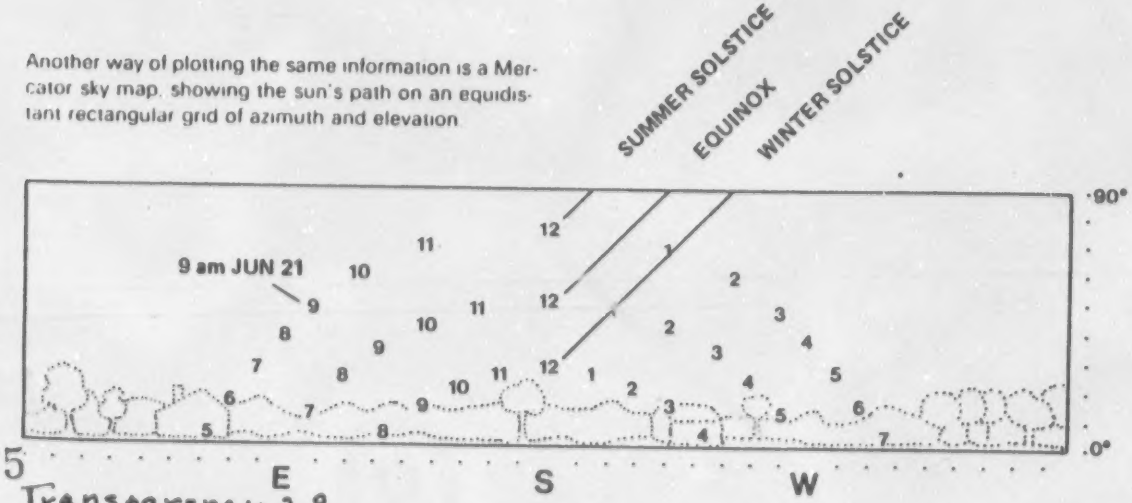
If the sun's path were traced on a spherical vault overhead, the result would look like this, as seen from the east side and from the top. Each day's path describes a circle around an axis pointing toward the North Pole, the axis being tilted from the horizon by the latitude angle, in this case 40°



A Sun Path Diagram, such as this one for latitude 40 North, is an equidistant circular graphic "map" of the azimuth (compass direction) and elevation (angle from the horizon) of the sun at all hours of the day for each day of the year.

2.17

Another way of plotting the same information is a Mercator sky map, showing the sun's path on an equidistant rectangular grid of azimuth and elevation.



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Transparency 2.9.

SOURCE: AIA Research Corporation, Solar Dwelling Design Concepts. Developed for the U.S. Department of Housing and Urban Development. May, 1976, p. 45.

ASSIGNMENT SHEET: LOCATING THE SUN

1. a. List two ways in which the constant tilt of the earth's axis affects human beings.

   b. Explain the importance of the Tropic of Cancer and the Tropic of Capricorn.

2. a. What information is needed to state the position of the sun in the sky at a specific time of any day of the year.

   b. Use Table 2 from "Solar Energy Utilization for Heating and Cooling" (1974, p. 59.4) to find the altitude of the sun on January 21, April 21, and July 21 at 1:00 p.m. (the table is for 40° North latitude.

UNIT TEST: LOCATING THE SUN

1. Match definitions to terms.

___a. Declination Angle

___b. Azimuth

___c. Solar Noon

___d. Latitude

___e. Solar Altitude

___f. Irradiation

___g. Insolation

1. Angle indicating distance north or south from the earth's equator
2. Exposure to radiant energy
3. Angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun
4. The amount of solar radiation actually striking the surface of the earth
5. Angle of sun's elevation above the horizon
6. An angle obtained by measuring from due south and rotating until facing the sun.
7. The time of day when the sun is due south of an observer.

2. Mark with a "T" the following statements about solar radiation which are true, and mark with an "F" those statements which are false.

___a. The earth rotates once around its own axis every 365.25 days.

___b. The axis of the earth's rotation is tilted 23.5°.

___c. The greatest amount of solar radiation is received at the point on the surface of the earth which is most perpendicular to the direct rays of the sun.

___d. The tilt of the earth's axis causes the constant change in the angle of declination.

___e. The spot on the earth most perpendicular to the direct rays of the sun moves from latitude 23.5° N to latitude 15.5° S.

___f. Variations in hours of daylight and in seasonal temperature differences are explained by the constant change in the angle of declination.

3. Complete the blanks in the following sentences using the words listed below:

1. Solar Azimuth
2. Insolation
3. Solar Altitude
4. Solar Noon

___a. The solar azimuth is defined to be 0° at _____.

___b. If one knows the (i) _____ and (ii) _____ for a given latitude, (iii) _____ values can be obtained.

___c. Tables are available which give _____ and _____ angles at different latitudes and for different hours of the day.

4. Place an "x" in front of the statements below which are true.

___a. It is impossible to know when house surfaces will be shaded.

___b. South-facing windows can be of value in a solar-heated house and still not cause cooling problems in the summer.

___c. In the northern hemisphere, during the summer, the sun can actually be north of an observer at certain times of the day.

___d. Roof overhangs are of no value in solar design.

___e. Flat surfaces which are perpendicular to the direct rays of the sun will collect solar energy efficiently.

ANSWERS TO ASSIGNMENT SHEET AND UNIT TEST: LOCATING THE SUN

Answer to Assignment 1

a. The constant tilt of the earth's axis causes season changes and the length of the day.

b. The Tropic of Cancer is at latitude 23.5° North, and the Tropic of Capricorn is at 23.5° South. During the year, the length of time required for the earth to move around the sun, the latitudinal spot on the earth nearest the sun moves between these two latitudes. The latitudinal angle is equal to the constant degree of tilt of the earth's axis.

Answer to Assignmant 2

a. Solar azimuth, solar altitude, and latitude.

b. Altitude at 40° latitude North at 1:00 p.m. on

Janaury	21	28.4°
April	21	58.7°
July	21	66.7°

Answers to Unit Test 1

a. 3

b. 6

c. 7

d. 1

e. 5

f. 2

g. 4

Answers to Unit Test 2

a. F

b. T

c. T

d. T

e. F

f. T

Answers to Unit Test 3

a. 4

b. i. 1

ii. 3

iii. 2

Interchangeable

c. 1,3

Answers to Unit Test 4

b,c,e

References

AIA Research Corporation. May 1976. Solar Dwelling Design Concepts. Prepared for the U.S. Department of Housing and Urban Development, Office of Policy Development, Office of Policy Development and Research. Washington, D.C.: U.S. Government Printing Office.

Baer, Steve. 1975. Sunspots, Collected Facts and Solar Fiction. Albuquerque, New Mexico: Zomeworks Corporation.

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Solar Energy Utilization for Heating and Cooling. 1974. Compiled by John I. Yellott for the American Society of Heating, Refrigerating and Air Conditioning Engineers. Washington, D.C.: U.S. Government Printing Office. Reprinted from Chapter 59 of the 1974 Ediction, Applications Volume, of the ASHRAE Guide and Data Book series.

UNIT III

SOLAR ENERGY SYSTEMS

UNIT OBJECTIVE

After completion of this unit, the participant should be able to explain the principles governing the operation and name the component parts of solar energy systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the participant should be able to

1. [illegible] terms about solar energy systems with the correct definitions.
2. Identify true statements referring to solar energy systems.

Terms and Definitions

System-a grouping together of parts that operate together for a common purpose (Forrester, 1972, p. 1-1).

Collector-a device for receiving solar radiation and converting it to heat in a fluid

Storage-the component in a solar energy system which retains the solar energy which has been collected for later use either at night or on cloudy days

Distribution-the component in a solar energy system whereby the thermal energy in storage is made available at the point of use

Active Solar Energy System-thermal energy is transported from the collectors to storage and then to the distribution system in a regulated way, using mechanical pumps and thermal controls.

Passive Solar Energy System-heat is transported by natural means, and the components are typically integrated into the basic design of the dwelling, so that few, if any, mechanical devices are needed in the system.

Radiation-any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Convection-when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

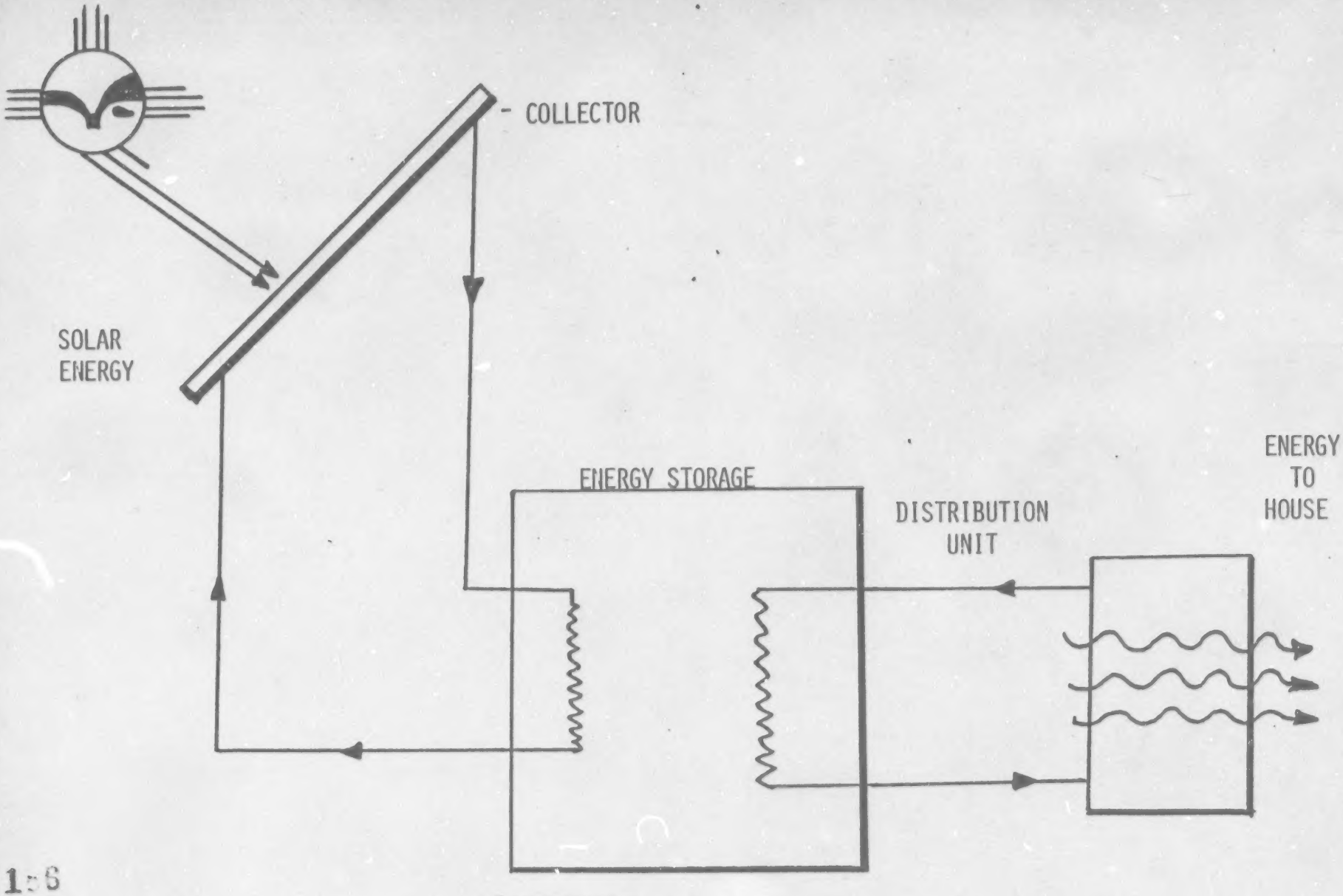
Conduction-heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Information Sheet

2. Systems

A system is a "grouping of parts that operate together for a common purpose" (Forrester, p. 1-1). We observe systems in nature, i.e., biological systems, ecological systems. And we design systems out of physical parts. An automobile is a physical system made of parts which must work together if the system is to fulfill its design purpose, in other words, if it is to provide transportation from one place to another. To understand a system, it is necessary to understand the parts and how they function. However, it is important to understand not only how the parts function individually, but also, how they function as a unified whole to accomplish the desired end. Very often, individual components may function very well individually and yet not function well at all when joined with the other components in the system. The parts of a system are interdependent. How one component functions will affect how other components function.

A solar energy system is a system designed to use solar radiation as an energy source. The system can be used to heat or cool dwellings, to heat domestic hot water, to heat a pool, and so on. The parts or components of a solar energy system are the collector, storage, and distribution. Transparency 3.1 represents schematically a typical solar energy system. Solar



1:6

Transparency 3.1

TYPICAL SOLAR ENERGY SYSTEM

radiation is absorbed by the collector, placed in storage, with or without the assistance of a transport medium, and distributed to the point of use.

Solar energy systems are usually classified as being either active or passive. In an active solar energy system, thermal energy is transported from the collectors to storage and then to the distribution system in a regulated way using thermal controls. It is necessary to use mechanical devices to pump the gas or liquid transport medium from the collectors to storage and/or to the interior of the dwelling.

In a passive solar energy system, heat is transported by natural means, by radiation, convection, or conduction. The components are typically integrated into the basic design of the dwelling--the windows, walls, floor, or ceiling.

ASSIGNMENT SHEET

1. Name three "systems", and explain why you think they are systems. Include a statement of the design purpose, list the components, and describe very briefly what might happen if one of the components failed or was changed in some way.

UNIT TEST-SYSTEMS

1. Match terms with definitions

___a. System

___b. Collector

___c. Storage

___d. Distribution

___e. Active Solar Energy System

___f. Passive Solar Energy System

___g. Radiation

___h. Convection

___i. Conduction

1. Heat is collected, then transported by natural means. The components are integrated into the basic structure of the building.

2. Heat transfer caused by molecular scale vibration.

3. The component of a solar energy system which carries heat to the point of use.

4. Components are designed to work together for a desired purpose.

5. Component designed to retain heat for long periods of time.

6. Moving air currents carry heat from a hot to a cold surface.

7. Heat waves transmit energy from a warmer surface to cooler surroundings.

8. Collected heat is transported through system by pumps regulated by thermal controls.

9. Receives solar radiation and converts it to heat.

2. Check the statements which are correct concerning systems generally or solar energy systems specifically.

___a. A system is designed to fulfill a specific purpose.

___b. Not only must the components in a system function well individually, but also they must function effectively within the unified whole.

___c. If a component functions well individually, it follows necessarily that it will function well within a specific system.

___d. Heat is transported by natural means in an active solar energy system.

___e. Convection and radiation are the only natural means of heat transfer.

ANSWERS TO ASSIGNMENT SHEET
AND UNIT III TEST

Answer to Assignment 1

Three systems might be (A) the circulatory system of the human body; (B) an ecological system, such as can be seen in the life balances in small, naturally occurring pond; and (C) a motorcycle. All are systems because they are made up of components which must function together if the entire system is to function.

A. The components of the circulatory system are the heart and the arteries, vessels, and veins. The purpose of the system is to distribute oxygen and needed nutrients to the cells in the body. If the heart stops beating, distribution ceases. If a valve in the heart fails to close, the blood will not be pumped; if a vein or artery were to open or close, circulation of the blood could not continue.

B. In a small pond, vegetation, insect life, and animal life function together to support life in the pond. Biological balances between these components can be very delicate. Wastes from insects and animals provide nutrients for the vegetation. The vegetation converts CO_2 into O_2 for the insects and small vertebrates and invertebrates. A food chain exists among these creatures, and if one link of the chain is destroyed all those creatures above it may die.

C. A motorcycle has a motor, a drive assembly, and a steering mechanism. Each of these components is also a subsystem

made up of smaller components. The total mechanism is designed to transport a person from point "A" to point "B". If the motor is not functioning or if the gears do not shift out of neutral, transportation will not occur.

Answers to Unit Test 1

a. 4

b. 9

c. 5

d. 3

e. 8

f. 1

g. 7

h. 6

i. 2

Answers to Unit Test 2

a,b

References

AIA Research Corporation. May 1976. Solar Dwelling Design Concepts. Prepared for the U.S. Department of Housing and Urban Development, Office of Policy Development, Office of Policy Development and Research. Washington, D.C.: U.S. Government Printing Office.

Forrester, Jay W. 1968. Principles of Systems. Cambridge, Mass.: Wright-Allen Press, Inc.

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Unit IV

Collectors

UNIT OBJECTIVES

After completion of this unit, the participant should be able to name the types of and function of the collector as a component in a solar energy system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

Upon completion of this unit, the student should be able to

1. Match terms related to collectors with their definitions.
2. Select from given statements those that accurately describe general concepts about collectors.
3. A. Identify the different types of flat-plate collectors.

   B. Select from a list the correct advantages and disadvantages associated with each type of flat-plate collector.

4. A. Match terms with descriptions of concentrating collectors.

   B. Select from a list the correct advantages and disadvantages associated with each type of concentrating collector.

5. Identify correct statements about passive collectors.

1. Terms and Definitions

Collector-a device for receiving solar radiation and converting it to heat in a fluid.

Insolation-the amount of solar radiation actually striking the surface of the earth.

Heat-transfer medium-a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use. Synonymous with heat-transport fluid.

Flat-plate collector-a class of collectors so named because of the large surface area exposed to the sun.

Concentrating collector-a class of collectors which use reflectors to focus solar radiation on a small area.

Clerestory window-a south-facing window in the wall of a room which rises above an adjoining roof; the window can be used to admit solar radiation.

Thermosyphoning-the principle that heated gasses and liquids rise naturally has been applied as a means of heat transport in passive solar energy systems. Heat built up within a wall or roof sturcture can be drawn off to heat interior spaces.

Fenestration-the placement, size, and design of windows and doors in a building.

Beadwall-a patented insulated window in which polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacumn-driven system.

Trombewall-a type of passive collector which makes use of a massive masonry wall, painted black and placed behind a south-facing wall of glass. Air trapped between the wall and the glass is heated, moves up over the wall and into the interior space.

Conduction-heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Convection-when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Radiation-any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

2. INTRODUCTION TO COLLECTORS

The collector can be any suitable surface which will absorb the incident radiation, or insolation, and convert it to usable thermal energy. (Note: In a photovoltaic collector, insolation is converted directly to electricity.) The thermal energy captured by the collector is transferred to a fluid within the collector. This fluid, a heat-transfer medium, is usually a gas or liquid which transports the thermal energy to storage or point of use.

Specific types of collectors to be discussed are listed below. Some collectors can be organized and operated independent of the unit they serve, i.e., the building. Collectors can be classified according to whether they are used in active or passive solar energy systems. The following are usually associated with active systems:

Flat-Plate Collectors

- Open-Water Collector
- Air-Cooled Collector
- Liquid-Cooled Collector

Concentrating Collectors

- Linear Concentrating Collector
- Circular Concentrating Collector

A second class of collectors can be referred to as passive collectors. Passive collectors serve as integral parts of the building unit. If a passive collector is modified, the entire design of the building would have to be modified. Some typical collectors used in passive solar systems are south-facing windows, greenhouses, skylights or clerestory windows, thermosyphoning roof or walls, and ponds (especially roof ponds).

Certain characteristics are common to all collectors. In general, a transparent sheet or plate is used to cover the absorbing surface of the collector. The absorbing surface, or absorber, is coated with a dark substance to increase absorption. Most of the solar radiation transmitted through the glass is absorbed and converted to heat. However, once heated, the absorber will

radiate heat away from it. The purpose of the cover plate is to reduce heat loss back to the atmosphere by convection or radiation. The cover plate, ususally made of glass or plastic, will trap heat radiated by the absorbing surface. While the solar radiation reaching the collector is generally in the form of ultraviolet or short-wavelength radiation, the heat radiated from the absorbing surface is characteristically long-wavelength radiation. Glass and some plastics will transmit short-wavelength radiation but absorb long-wavelength radiation. These characteristics of the materials explain why the heat is trapped in the collector.

3. ACTIVE COLLECTORS

Flat-Plate Collectors

When talking about solar collectors, most people automatically think of a flat-plate collector. The flat-plate collector is simple and widely used. It absorbs both diffuse and direct radiation. The collector can be oriented to catch the optimum insolation at a desired time. Temperatures to 250° F can be obtained; these temperatures are well within the range needed for heating interior spaces or domestic hot water.

The flat-plate collector works best when the collector surface is perpendicular to the direct rays of the sun. The tilt should be determined by the season of year when the most solar radiation is needed for the solar energy system; however, the tilt need not be exact. The amount of sunshine intercepted by a plane misaligned a certain number of degrees has been calculated (see Transparency 4.1)

A flat-plate collector usually consists of the following: one or two cover plates; a dark-colored absorbing surface insulated on the back to reduce heat loss; and a transporting fluid, either air or gas, which absorbs the heat and carries it to storage or to points of use (see Transparency 4.2) The type of fluid used in the flat-plate collector futher defines the type of flat-plate collector. Often the type of fluid used is determined by other components in the system.

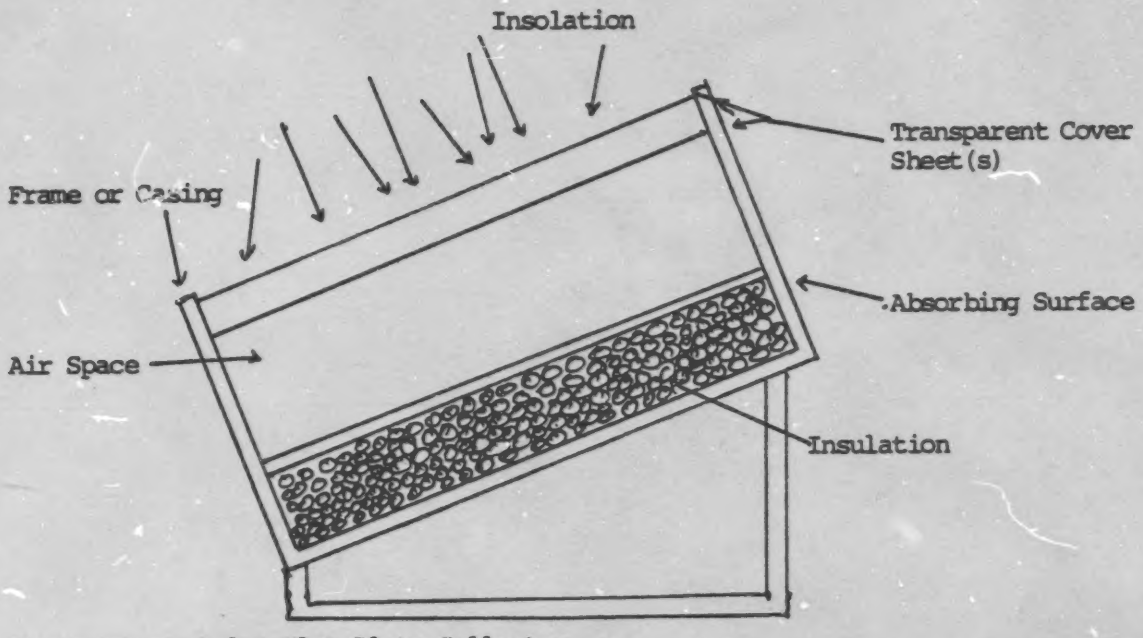
Percent of Possible Sunshine Intercepted by a Plane Misaligned x Degrees.

Degrees	Percent
0	100.0
5	99.6
10	98.5
15	96.5
20	94.0
25	90.6
30	86.6
35	81.9
40	76.6
45	70.7
50	64.3
55	57.4
60	50.0
65	42.3
70	34.2
75	25.8
80	17.4
85	8.7
90	0.0

Transparency 4.1

Evidently, when orienting planes to receive sunlight, pretty close is close enough. If your angle is off as much as 25 degrees, you still are intercepting over 90% of the possible sunlight.

Source: Steve Baer, Sunspots (Albuquerque, New Mexico: Zomeworks, Inc., 1975), p. 7. Reprinted by permission of the author.



Transparency 4.2 A Flat-Plate Collector.

Open-Water Collectors. Water makes a good heat transport fluid for use in a flat-plate collector. It requires a smaller space for piping, and it absorbs heat readily. In an open-collector, such as Harry Thomason has developed, the water is trickled over the absorber surface. The absorber surface is usually corrugated roofing material which is painted black. The water is distributed across the top of the collectors and trickled down the grooves where the water absorbs heat from the absorbing surface, and is then caught in a trough at the bottom and piped to storage. Without a cover, there will be heat losses by evaporation. If a glass cover is used, to prevent evaporation, water condensation on the surface can reduce the efficiency of the collector. A second cover sheet minimizes this problem.

Another possibility is to place a second sheet of the corrugated roofing over the first, leaving only a small passage for the water so that the water will be in contact with both surfaces. Open-water collectors have been operated successfully in the Washington, D.C. area. In cold climates with hard freezes, these collectors should be evaluated carefully before installation.

This type of collector can be constructed at the building site. A collector which can be constructed at the building site from easily obtained materials will be less expensive than a factory-produced collector which must be shipped intact to the site. If there comes a time when demand is sufficient to justify mass production of a standard collector type, this saving may be reduced.

Hot-Liquid Collectors. Most collectors using a liquid as the heat transport medium pipe the liquid through the collector box. The pipes usually are attached to the absorber plate, and the heat transfer is by conduction. To increase heat transfer by conduction, greater absorber surface area must be in direct contact with the heat transfer medium. Rectangular pipe is used rather than round tubing, thus increasing the amount of surface contact and effecting better heat transfer. The heated liquid is transported to storage, where the heat is transferred to the storage medium.

There are problems involved in using a liquid transport medium. If water is used, freezing is a real danger: and repairs can be costly. Controls can be added to the system to prevent freezing, but the controls themselves can be costly. Also, leaks may occur. If solutions such as antifreeze are used, corrosion can decrease the efficiency of the collector. However, liquid collectors are efficient in collecting and transporting heat. The liquids used absorb heat readily and require relatively smaller space for piping than does air.

Hot-Air Collectors. Air can be used as the transport medium. By using air, problems associated with freezing, leaks, and corrosion are overcome. Also, the heated air can be pumped directly into the interior space to be heated or it can be pumped to storage.

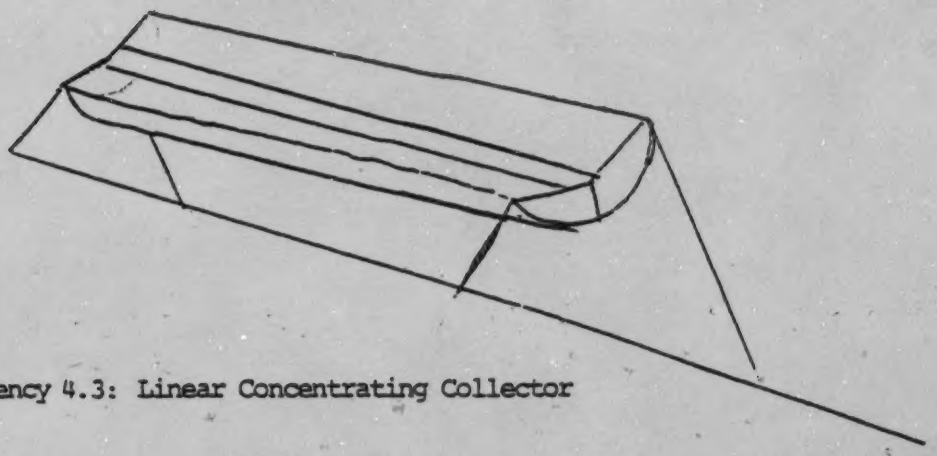
There are problems associated with using air as the transport medium. A much larger volume of air is needed to transport heat than is needed if a liquid is used as the transport medium. The transfer of heat from the absorber to air presents some problems in efficiency. Often, a finned apparatus, screenwire, or some other method is needed to increase contact of the heated surface with the air (Environmental Research Laboratory, Reprint No. 43, Tucson, Arizona: Tucson International Airport).

4. CONCENTRATING COLLECTORS

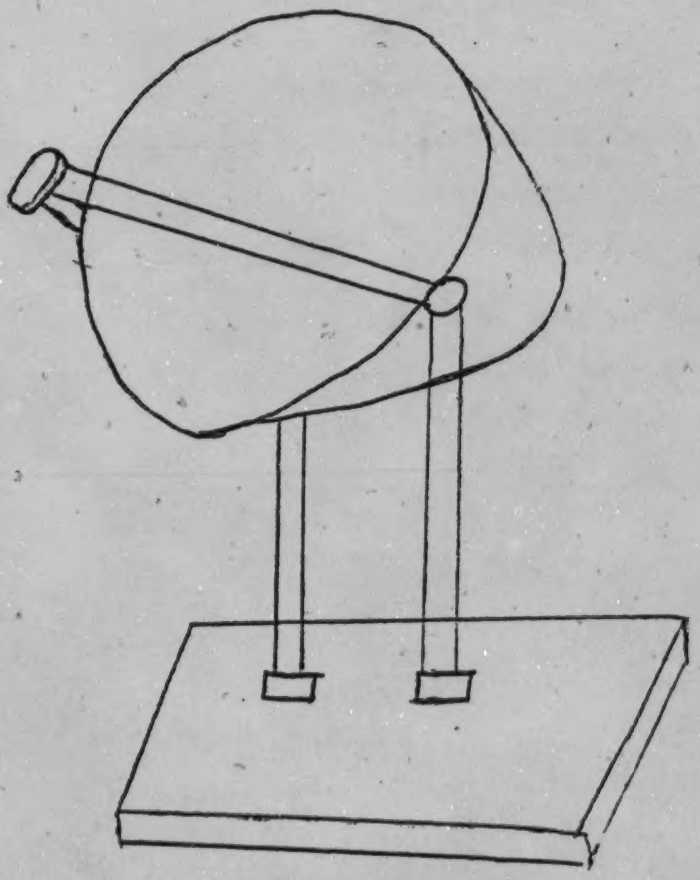
Concentrating collectors use reflectors to increase the amount of radiation striking a small area. The target area may be either a tube or a point which absorbs the thermal heat. A major problem with concentrating collectors is that they require direct radiation. Thus they will not absorb heat on a cloudy day. Also, concentrating collectors require tracking devices to follow the sun. Another problem is that the reflecting surface must be kept clean. To date, concentrating collectors have not been used extensively in systems designed for interior heating of dwellings. A major advantage of concentrating collectors is that less surface area is needed to collect solar energy in an amount equal to that collected by a flat-plate collector.

Linear Concentrating Collectors. Linear concentrating collectors reflect radiation onto a pipe or tube, which is the absorber. The heat-transport medium circulates through the absorber and is then moved to the point of use or to storage. Fairly accurate orientation to the sun must be maintained, both in an east-west and north-south direction. A linear concentrating collector is illustrated on Transparency 4.3.

Circular Concentrating Collectors. Circular concentrating collectors are dish-shaped to focus radiation on a single point. An absorber is located on the point. The heat absorbed is carried to point of use or storage by a transport fluid. Circular concentrating collectors must track the sun to collect direct rays. However, high temperatures can be achieved which may make their use highly desirable (see Transparency 4.4).



Transparency 4.3: Linear Concentrating Collector



Transparency 4.4: Circular Concentrating Collector

5. PASSIVE COLLECTORS

A passive solar energy system is designed to make the greatest possible use of natural heat transfer processes—conduction, convection, and radiation. Usually, the heat collector and the storage areas are an integral part of the living space, and it is impossible entirely to divorce the two components in a passive system. However, homes are now being built with one or several combinations of the individual components. The emphasis here will be on the collector component.

Fenestration

Windows admit into a room solar radiaton which can then be absorbed by surfaces within the building. South-facing windows are used to increase heat gain. The major drawback of south-facing windows is the enormous amount of heat which is collected. To reduce over-heating, however, massive walls and floors can be used to absorb and store the heat. How massive the walls and floors must be can be calculated so that the mass does not become a drawback. If the mass is too great, it may take up too much of the heat acquired or it may take too long to warm up after periods of low temperature.

Greenhouses

Greenhouses, on the south side of a house, are also used to collect heat. However, to avoid heat loss, some kind of insulation must be available. Beadwalls are one possibility. A Beadwall is a patented system involving a space between two sheets of glass or plastic. Polystyrene beads are blown into or pulled out of the space by a vacumn-driven system. Panels of insulating material can also be used for insulating the greenhouse to avoid

heat loss at night or on cloudy days. A massive floor of rock or masonry or a masonry wall between the greenhouse and dwelling may be needed to avoid overheating.

Skylights and Clerestory Windows

Skylights and clerestory windows can also be used to collect heat from the sun. It is important to note that both may need to be insulated at night or on cloudy days. Insulated shutters are available for this purpose. Windows placed in the ceiling or high in a wall can be a problem because the heat could be trapped near the ceiling. The heat admitted through skylights and clerestory windows will enter at a high point in the building. A return air register can be placed at a point high in the room. The heat gained from solar radiation and trapped at the ceiling can thus be circulated to floor level. A fan placed in the duct will facilitate the circulating process.

The Thermosyphoning Concept

The thermosyphoning concept, using the walls and roof, can also collect solar energy for use in heating interior spaces. The fact that hot gases or liquids rise can be used to employ a natural heat transport system. If solar-heated air, trapped in an air space within a wall or roof, is warmer than the air in the interior of the building, the solar-heated air can be drawn off through vents. If the exterior wall or roof is made of glass or plastic, much higher temperatures can be obtained and the thermosyphoning technique will be more efficient.

A special application of the thermosyphoning technique is the Trombe Wall. Placed behind a south-facing wall of glass is a massive masonry wall, painted black. An air space between the window and the wall traps the heated air, which

moves up and over the wall into the room. Vents at the bottom of the wall allow colder air from the interior to enter the space, and as the air is heated it moves up and finally re-enters the interior of the house.

Roof Ponds

Roof ponds can provide both heating and cooling of buildings. The pond is usually placed on the roof. However, the pond can be put in the interior of the building with the liquid, usually water, circulated to the roof. Presently, designers are experimenting with using pools completely separated from the building to collect and store heat. Controls are needed if roof ponds are used as collectors to maintain the most comfortable temperature level within the building. By using insulated panels to either cover or uncover the pond or by filling or emptying the pond, heating and cooling needs can be satisfied.

When the ponds are on the roof, the water is usually contained in black plastic bags. Some arrangements do not use a transparent roof covering because then during the night evaporation can be used, as well as conduction and radiation, to help cool the water.

Solar ponds are most effective in warm, dry areas with cool or cold nights. In warm climates, the ponds would be covered during the day. Cooling is thus accomplished by allowing natural radiation to the sky at night. If the water is cooled at night, then during the day time, the heat from the building can be absorbed by the ponds for radiation at night. If heat is needed, the insulating panels covering the pond are removed during the day so the water can absorb heat and then placed over the pond at night to retain the solar heat collected during the day. Solar ponds are not effective in areas of the country with high humidity. High humidity interferes with night

radiation during times when cooling is desired.

There are real advantages to placing the solar ponds on a flat roof. In southern climates, if the roof is flat, there is no problem about how the building is oriented with regard to the sun. In northern climates, the ponds should be covered, tilted, and placed under a transparent cover for best results. The insulation panels can be moved with the aid of fairly simple machinery and stored, perhaps over the garage or a patio covering. If the pond is in direct contact with the interior space and spread over the entire roof area of the dwelling space, heat is radiated evenly throughout the living area.

ASSIGNMENT SHEET

1. List the advantages and disadvantages of an open-water collector.

Advantages	Disadvantages

2. List the advantages and disadvantages of a hot-liquid collector.

Advantages	Disadvantages

3. List the advantages and disadvantages of a hot-air collector.

Advantages	Disadvantages

4. List the advantages and disadvantages of a linear concentrating collector.

Advantages	Disadvantages

5. List the advantages and disadvantages of a circular concentrating collector.

Advantages	Disadvantages

ACTIVITIES--MAKING A COLLECTOR

Activity 1

A. Materials Needed

1. Two cans with covers

2. Black paint

3. Four glass jars. Size is important. Each can must fit inside one jar which will in turn fit inside the second jar.

4. Thermometer

B. Procedure

1. Paint one can black and allow paint to dry.

2. Fill both cans with water and seal.

3. Place a can inside each of the smaller jars.

4. Lay the jars on their side where the direct rays of the sun will strike the jars.

5. After approximately 20 minutes (depending on the size of the containers) read and record the water temperature in each can.

6. Repeat the activity, but this time, place each can and jar inside the second glass container and wait for approximately 20 minutes before reading the temperature of the water.

7. Leave these "collectors" where the direct rays from the sun will strike the containers for about one hour. Read and record the temperatures again.

C. What Has Been Learned?

1. What temperature differences were observed?

2. How could higher temperatures have been obtained (consider using insulation and reflectors)?

3. Can you explain why a difference in temperature was observed when two glass containers were used instead of one?

Activity 2

A. Materials Needed

1. A 2' x 4' rectangular box with sides approximately 4" high

2. Insulation

3. Black paint

4. Transparent glass or plastic cover

5. A large quantity of cans of the same size; beer cans or vegetable cans would be excellent.

6. Hole cutter

7. Can opener

8. Epoxy glue or caulking material

9. Thermometers

B. Procedure

1. Make two 4 1/2 feet tubes by cutting off can lids and bottoms and gluing the cans together.

2. Remove one-half the lid and the bottom of each can. In this way, the movement of air through the tube will be impeded and more heat will be absorbed. Leave the lids at each end of the tube intact.

3. Paint the one tube black.

4. Place insulation in the bottom of the box.

5. Paint the surface of the insulation black.

6. Cut holes in either end of the box. Place cans in box so that the cans will protrude slightly at each end. Caulk around opening.

7. Cut 2-inch openings in each end of tube.

8. Place transparent cover over collector.

9. Tilt collector so that the flat, transparent surface is normal (perpendicular) to the direct rays of the sun. Be sure the holes in the tubes are not blocked.

10. After approximately 30 minutes, check the temperature of the air entering the collector at the bottom and the air escaping at the top. Be careful to shade the thermometer when taking temperature readings.

C. What Has Been Learned?

1. Is there any difference in temperature between the air rising in the tubes which were painted black and those left unpainted.

2. Materials can be a serious problem in building collectors because the materials must withstand high temperatures and prolonged exposure to solar radiation. Plastics, caulks, adhesives, and paints are of especial importance. Where might one obtain information about materials?

UNIT TEST--COLLECTORS

1. Match Definitions with the correct terms.

___A. Collector

___B. Insolation

___C. Heat-transfer medium

___D. Flat-plate collector

___E. Concentrating collector

___F. Clerestory window

___G. Fenestration

___H. Thermosyphoning

___I. Beadwall

___J. Trombe Wall

___K. Conduction

___L. Convection

___M. Radiation

1. Placement, size, and design of windows and doors in a building.

2. A means of heat transport making use of the principle that heated gasses and liquids rise naturally.

3. The amount of solar radiation actually striking the surface of the earth.

4. When a hot surface and a cold surface are separated by a thin layer of air, moving air currents are established which carry heat from the hot to the cold surface.

5. When two surfaces are in direct physical contact, heat transfer occurs by molecular scale vibration.

6. A type of passive collector which uses a black masonry wall and a glass wall with an air space in between.

7. A component in a solar energy system which receives solar radiation and converts it to heat.

8. A class of collectors which expose a large surface area to the sun.

9. A south-facing window in the wall of a room which rises above an adjoining roof.

10. Polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacumn-driven system.

11. An object warmer than it's surroundings transmits heat waves and, thus, emits energy.

12. A liquid or gas which absorbs heat and moves it from the collector to storage or to point of use.

13. A class of collector which reflects radiation and focusses it on a small area.

2. Select from the statements written below those which accurately describe general concepts about collectors and mark them with an "x".

___A. Any surface which will absorb solar radiation and convert it to heat can be called a collector.

___B. If a surface is coated with a dark substance, it will increase the rate of absorption of radiation.

___C. Open-water collectors are a type of concentrating collector.

___D. The transparent sheet which covers the absorbing surface of the collector serves mainly to keep the absorbing surface clean.

___E. After radiant energy is converted to heat, it is transported away to storage or point of use in a solar energy system.

___F. Heat is trapped in the collector by the transparent covering.

___G. Once the absorbing surface of the collector has absorbed the radiant energy, there is no danger of heat loss.

___H. A south-facing window can serve as a solar collector.

3. Flat-Plate Collectors

A. Identify the different types of flat-plate collectors by filling in the blanks with the proper term.

a. Open-water collectors

b. Hot-liquid collectors

c. Hot-air collectors

____1. The liquid which serves as the heat-transport medium is piped through the collector box.

____2. Air is pumped through the collector box.

____3. The heat-transport medium, water, is trickled over the absorber surface, which is usually made of a corrugated roofing material.

B. Select from the following list, the advantages and disadvantages associated with the three types of flat-plate collectors. Place letters from the list on the appropriate lines for each type of collector. Each letter may be used more than once.

1. Open-water collector

Advantages_____

_____

Disadvantages_____

_____

2. Hot-liquid collectors

Advantages_____

_____

Disadvantages_____

_____

3. Hot-air collectors

Advantages_____

_____

Disadvantages_____

_____

a. Freezing

b. Corrosion

C. Heat losses through evaporation if cover is not used.

d. Leaking

e. Heat-transfer medium can be pumped directly to point of use.

f. Usually less expensive

g. Water or other liquid is an efficient heat-transport fluid.

h. If cover is used condensation may interfere with rate of absorption

i. Because heat transfer is a problem, greater direct contact of heat-transfer medium with absorber surface is needed.

j. A larger volume of the heat transfer medium must be used.

k. No problems with freezing

l. No problems with corrosion

m. No problems with leakage

n. A smaller piping system is needed to carry the heat-transfer medium.

o. A larger piping system is needed to carry the heat-transfer medium.

4. Concentrating Collectors

A. Match terms with the appropriate description.

_____a. Not a collector

_____b. Linear concentrating collector

_____c. Circular Concentrating collector

1. Radiation is reflected onto a pipe or tube through which the heat transport medium is circulated.

2. The radiation is focussed and reflected onto a single point.

3. Radiation is reflected onto a single spot on the moon.

B. Select from the following list the advantages and disadvantages associated with the two types of concentrating collectors. Place letters from the list on the appropriate lines for each type of collector. Each letter may be used more than once.

1. Linear Concentrating Collector

Advantages_____

_____

Disadvantages_____

_____

2. Circular Concentrating Collector

Advantages_____

_____

Disadvantages_____

_____

a. Only a small area is needed to collect a large amount of energy.

b. The collector must be oriented exactly with the sun.

c. Orientation with the sun must be fairly accurate.

d. Absorbs only direct radiation

e. High temperatures may be obtained.

f. The reflecting surface must be kept clean.

5. Passive Collectors

Identify and mark with a "T" the statements below which accurately describe passive collectors. Mark false statements with an "F".

___a. South-facing windows collect only small amounts of heat.

___b. There are no drawbacks to using greenhouses as passive collectors.

___c. Because of the natural movements of heated air, air can be used as the heat-transport medium in passively heated dwellings.

___d. Massive walls and floors of rock or masonry have no effect on the amount of heat which must be collected.

___e. The heat admitted through skylights and clerestory windows enters at a high point in the room and is trapped there.

___f. In a Trombe Wall, vents are placed at the top and bottom of the wall.

___g. The purpose of the vents in the Trombe Walls is to allow warm air to enter the interior of the dwelling as it rises and to allow cooler air to be moved from the interior of the dwelling to be reheated.

___h. Roof ponds are a type of passive solar collector.

___i. The heat collector and the heat storage components can be entirely separated in all passive solar energy systems.

___j. If windows are used for thermal gain, the windows must be insulated at night.

___k. Roof ponds can only cool buildings.

___l. Roof ponds work best in areas with high humidity.

___m. Solar ponds may be completely separated from the building.

___n. If a greenhouse is used to collect heat, the windows will need to be insulated at night and a massive floor or wall will be needed to absorb the heat.

ANSWERS TO ASSIGNMENT SHEETS AND UNIT IV TEST

Answers to Assignment 1

Advantages	Disadvantages
Water is a good heat transport medium	Without transparent cover heat is lost to evaporation.
Collector is inexpensive	With transparent cover, condensation can be a problem.
Smaller piping system is needed to carry the heat-transport medium	Freezing
	Corrosion
	Leakage

Answers to Assignment 2

Advantages	Disadvantages
Water is a good heat transport medium	Freezing
Smaller piping system is needed to carry the heat transport medium	Leakage
	Corrosion
	Heat transfer is by conduction, meaning that contact of heat transfer medium with absorber must be maximized.

Answers to Assignment 3

Advantages	Disadvantages
Does not freeze or corrode	Larger volume of heat transport medium is needed
Leakage is not a problem	Requires large duct work
Air can be pumped directly to point of use	Heat transfer from absorber to air is not efficient

Answers to Assignment 4

Advantages	Disadvantages
Small area is needed to collect large amounts of energy	Orientation with sun must be fairly accurate
High temperatures may be obtained	Absorbs only direct radiation
	The reflecting surface must be kept clean

Answers to Assignment 5

Advantages	Disadvantages
Small area collects large amounts of energy	Collector must be oriented exactly with sun
High temperatures may be obtained	Absorbs only direct radiation
	Reflecting surface must be kept clean

Answers to Unit Test 1

A. 7

B. 3

C. 12

D. 8

E. 13

F. 9

G. 1

H. 2

I. 10

J. 6

k. 5

l. 4

m. 11

Answer to Unit Test 2

A, B, E, F, H

Answer to Unit Test 3

A. 1. b

2. c

3. a

B. 1. Advantages f,g,n

Disadvantages a,b,c,d,h

2. Advantages g,n

Disadvantages a,b,d,i

3. Advantages e,k,l,m

Disadvantages i,j,o

Answers to Unit Test 4

A. 1. b

2. c

3. a

B. 1. Advantages a,e

Disadvantages c,d,f

2. Advantages a,e

Disadvantages b,d,f

Answers to Unit Test 5

a. F	f. T	k. F
b. F	g. T	l. F
c. T	h. T	m. T
d. F	i. F	n. T
e. T	j. T	

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UNIT V

STORAGE

UNIT OBJECTIVE

After completion of this unit, the participant should be able to name the types of and function of the storage component of a solar energy system. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the participant should be able to

1. Recognize correct statements referring to the storage component.
2. Identify which statements about passive storage are true and which are false.
3. Select from a list the correct advantages and disadvantages associated with each of three types of active storage systems.

Information Sheet

THE STORAGE COMPONENT

Energy in the form of direct or diffuse solar radiation will not be available for collection and use at night or on cloudy days. If the solar energy system is to be of value, the energy must be collected when it is available and stored for later use. The heat can be stored by raising the temperature of such substances as rocks, water, concrete, or other masonry. Another method now being investigated is to use the energy to cause changes of state, such as changing a solid to a liquid.

The type of storage used in a particular system may depend upon the type of collector used for a specific building. However, considerations about storage materials--their cost, operation, and size--must be taken into account in planning the entire solar energy system.

2. HEAT STORAGE IN PASSIVE SYSTEMS

The solar radiation received from south-facing windows or transparent panels increases the temperature of room air and surfaces exposed to the sun's rays. As such, the room's air and exposed surfaces (walls, floors, furniture) are the solar storage component for a window wall, greenhouse, or transparent panel which collects the radiation. For most situations, the storage capacity of the air and surfaces will not be sufficient for long periods of heating demand. Additionally, in the process of "charging" the storage, the space may become overheated and possibly extremely uncomfortable for the occupants.

In order to reduce the overheating effect, masonry surfaces such as concrete, brick, tile, or stone on the floor or on the walls can be used for their heat storage capacity, absorbing the heat during the day and radiating it later for several hours or more. The storage effect of a particular floor or wall can be calculated as a function of the specific heat of the masonry, its volume and weight, and the expected temperature differences it will experience throughout the day. Too great a storage effect in the exposed room surfaces can have a negative effect on occupant comfort or fuel consumption if the morning "reheat" time of the materials is too long. However, properly designed, the thermal mass of construction materials can play a significant role in an integrated solar dwelling design.

To use effectively the radiation stored in the air and room surfaces, careful attention must be given to minimizing the loss of heat at night or when collection is not occurring. Insulated drapes, shutters, and other such devices are necessary to reduce heat loss and increase the use of trapped heat through windows. The room size; the window placement; the material composition, volume, and weight; and the expected temperature difference will also determine the performance of the solar storage. The exterior side of masonry walls used for thermal storage should be insulated to prevent heat loss from the walls.

A more direct application of this storage concept involves the placement of a glass or transparent wall over an exposed masonry surface, such as in the Trombe Wall. The exposed surface serves as the collector and as the heat store. The collecting surface is painted a dark color and is located directly behind the transparent surface. The thermal conductivity and specific heat of the wall material and the expected temperature range will determine the volume of the wall. The radiation time-lag must be accurately calculated to assure proper heating of the space. It is sometimes necessary to place insulation on the room side of the storage wall to avoid overheating the space. The exposed masonry storage method is frequently used in conjunction with interior and exterior vents to control the heat distribution to the space or to another storage system.

A variation of exposing a masonry surface to solar radiation is to expose containers filled with water. The exposed water containers may be placed just inside a glass south-facing wall. The sides of the containers facing the transparent wall are painted black and serve as collecting surfaces. To retain heat collected in this manner, moveable insulation should be used to cover the south-facing wall at night. Roof ponds function in much the same manner, collecting and storing heat during the daytime. Likewise, the water-filled containers will reradiate heat to the sky at night during the summer and thus can be used for cooling the building as well. Careful calculations are required to properly size the storage capacity. Also, thermal controls such as interior and exterior vents may be necessary to assure a proper lag-time and to avoid overheating.

3. HEAT STORAGE IN ACTIVE SYSTEMS

Rock Storage

Rock storage is most often associated with flat-plate collectors using air as the transport medium. Pebble beds or rock piles contained in an insulated storage unit have sufficient heat capacity to provide heat for extended sunless periods. The rock storage is heated as air from the collector is forced through the rock container by a blower. Rock storage will require approximately 2 1/2 times the volume of water storage, assuming the same temperature range. For example, a rock pile with a void space of one-third the total volume can store approximately 23 Btu/cubic feet/degree F. However, rocks can be used to store heat at temperatures above 212^{O} F.

A convenient rock size for storing solar heat is about two inches in diameter. A decrease in pebble size increases the air flow resistance through the storage and may affect blower and duct size and distribution efficiency. Rock storage does not have to be in close proximity to the collector. However, as the distance increases, the heat transfer losses between the heated air and the rocks also increases and larger air ducts and more electrical power are generally required for moving air between the collector, storage, and heated spaces.

Rock beds, while bulky, require little or no maintenance, and rock is cheap. Hot air gives up its heat quickly to the rocks, and elaborate heat exchangers such as are needed for liquid systems are not needed with air and rock.

Water Storage

Water has the highest heat capacity per pound of any ordinary material. It is also very inexpensive and therefore is an attractive storage and heat-transfer medium. However, it does require a large storage tank which may be expensive. It is sometimes practical to compartmentalize the storage tank to control temperature gradients (different temperatures within the storage tank) and to maintain an efficient heat transfer. Potential disadvantages of water storage include freezing, corrosion, and leakage.

Water storage tanks must be protected from freezing if located outside the dwelling. Also, the tank must be heavily insulated to prevent loss of the stored heat. Steel tanks are subject to corrosion unless rust and corrosion inhibitors are added, but then the water cannot be used for most household purposes. A plastic liner would solve the rust and corrosion.problems, but the types of plastic needed to store large quantities of water at high temperatures are expensive. Concrete is safe, durable, and relatively inexpensive; but if a leak does occur, it is difficult to repair.

Heat is generally transferred to and from storage by a working fluid circulated by an electric pump. The heated working fluid itself may be placed in storage or its heat transferred to the storage tank by a heat exchanger. The process of heat transfer to water is more efficient than to rock, and, therefore, less surface for the heat exchanger is required. However, care must be taken to guard aganist contamination of water intended for household use by the heated working fluid. This warning applies mainly when antifreeze or a rust inhibitor

are used in the heat transport medium, for these substances may be toxic.

Systems using a liquid transport and transfer medium are better suited for use with domestic hot water heaters. Thus if the solar energy system is planned to include the use of solar energy for heating water for domestic use, a liquid system may be preferred. Also, the availability of liquid system components makes liquid systems more attractive for the time being. Although air systems were developed earlier than were the liquid systems, the latter have been used more frequently in recent years, which accounts for the availability of components for liquid systems.

Change-of-State Storage

Processes which induce a change of state from a solid to a liquid when heated can be used to store energy. The change in state permits the storage of more heat per pound than if the material did not change composition. When a material such as Glauber's salts is cooled and goes from a liquid to solid state, it gives off this extra heat. This method, however, is still in the experimental state.

The great advantage of change-of-state storage is that it can contain a great amount of heat in a limited space and at limited weight. Let's say that the objective of a storage system is to hold 200,000 Btu's at 100-160° F. Water systems would need 53 cubic feet at 3,300 pounds, rocks would need 175 cubic feet at 17,500 pounds, while Glauber's salts would require only 19 cubic feet at 1,740 pounds. In addition, such salts are obtainable at relatively reasonable prices.

Salt storage, however, has a number of major limitations. The salts can only go through so many cycles before their natural state is altered to the point whereby they lose their capacity to successfully store heat. There are some chemical additions which act to prolong the number of cycles considerably, and there are some interesting experiments which, if successful, may dynamically prolong the life span.

Although salts are economical, present costs for containerization and transportation are fairly expensive. Mass production could bring these costs down dramatically.

ASSIGNMENT SHEET: UNIT V

1. A basement which is below ground and has concrete walls and floor is almost always cold. Large industrial buildings are frequently built with cement walls and concrete floors. The interior space is often very cool or even cold. Does any of the material in this unit offer an explanation as to why? If so, explain.

2. Why would it take large amounts of energy to heat the interior spaces described above?

3. List the advantages and disadvantages of using rock storage.

4. List the advantages and disadvantages of using water storage.

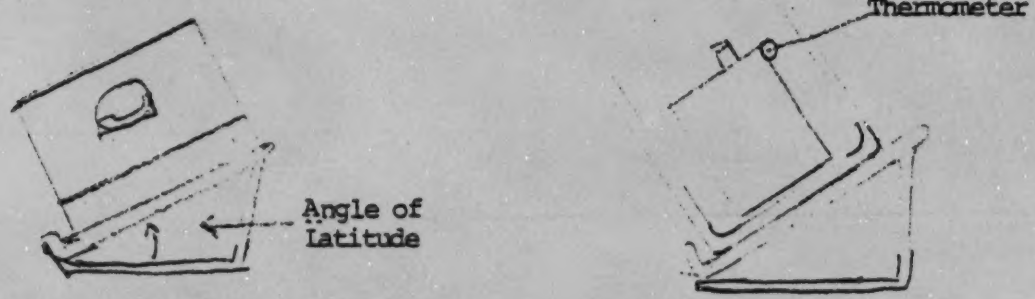
ACTIVITY: STORAGE

A. Materials Needed

1. A. large, well-insulated ice chest (lid off)
2. A clear cover
3. Two thermometers
4. Props for supporting the chest at the latitude angle
5. Five-gallon can painted black, with rubber gasket in screw-top lid
6. Wire
7. Graph paper

B. Procedure

1. Place the chest on the standards with the long axis of the chest pointing east-west and the open top facing south.
2. Using the standards to support the box, tilt the box south at an angle equal to the latitude.
3. Fill the 5-gallon can with water. Be sure the rubber gasket, which can be cut from an inner tube, is flat and in place. Slip the thermometer into a wire holder attached at the back of the 5-gallon can, and place the can in the chest with the thermometer at the top back of the can, i.e., out of the sun. Orient the thermometer so that readings can be taken without uncovering the box.



SOURCE: Activity furnished by Zomeworks Corporation, P.O. Box 712, Albuquerque, New Mexico 87103.

4. Slip the vinyl cover over the chest--some wire or string or tape should be wrapped around the cover to keep it from blowing off.

5. Hang the air thermometer from a wire at the back of the case, again, out of the sun--in the shadow of the chest.

6.a. Read the thermometers every 2 hours throughout a 24-hour period, and record the readings for each thermometer.

b. Read the thermometers at 8:00 a.m. and 8:00 p.m. for 7 consecutive days.

7. Plot the temperature readings for both thermometers over the 24-hour period.

C. What Has Been Learned?

The sun heats the water, but the water loses heat to the surroundings. The water temperature rises on sunny days. The temperature falls during the night or during cloudy weather. On some cloudy days when the clouds are thin and the sky is bright, the temperature may stay even or rise slightly.

The box does not measure the sunshine or the cold very accurately, but it does show the battle lines between the two and this is what is important to a solar-heated house.

The box is not a model of a solar-heated house. The temperature fluctuates much more in the box than in a house.

1. What differences are there in the temperature readings for the two thermometers?

2. Does the temperature inside the box fluctuate more or less than the temperature outside the box?

3. How do the fluctuations in the two temperature readings relate to each other?

UNIT TEST V: STORAGE

1. Check correct statements referring to the storage component with an X.

_____a. If a solar energy system is to be of value, the energy which is collected must be available for later use.

_____b. Heat can be stored in water, rocks, and concrete, among other possible materials.

_____c. Changing a solid to a liquid does not involve the use of energy.

_____d. The type of collector used has no effect on storage.

2. Mark with a "T" those statements about passive storage which are true, and identify with "F" those statements which are false.

_____a. When south-facing windows are used as the collectors, the best storage is the air itself and the furniture and walls.

_____b. To reduce overheating, masonry and concrete walls and floors can be used to store heat.

_____c. Overheating is not a problem in a passive system using south-facing windows to collect heat.

_____d. If the mass of concrete and masonry is too great, fuel consumption from an auxiliary heating system may go up.

_____e. The performance of solar storage in passive systems can be optimized by proper calculation of the storage mass needed.

_____f. It's impossible to calculate the storage effect of exposed room surfaces in passive storage.

_____g. Passive solar energy systems require that there be no windows in the dwelling.

_____h. If exterior masonry walls are used for their heat storage capacity, the internal surface must be well insulated.

_____i. Water can be used as the storage component in a passive energy system.

_____j. Water storage is effective for heating and cooling a dwelling.

3. Select from the following list the advantages and disadvantages associated with the three types of active storage. Place numbers from the list on the appropriate lines for each type of storage arrangement. Each number may be used more than once.

A. Rock Storage

Advantages_____

_____

Disadvantages_____

_____

B. Water Storage

Advantages_____

_____

Disadvantages_____

_____

C. Change-of-State Storage

Advantages_____

_____

Disadvantages_____

_____

1. Contains a great amount of heat in a limited space and at a limited weight.
2. Since it is most frequently used, components are readily available.
3. After extended use, the storage capacity is lost.
4. Freezing is a problem.
5. Freezing is not a problem
6. Corrosion is a problem.
7. Corrosion is not a problem.
8. Leakage is a problem.
9. Leakage is not a problem.

10. Finding an effective storage container is a problem.
11. Container is not a problem.
12. It can store heat at high temperatures.
13. The storage medium is bulky.
14. It has a high heat capacity per pound.
15. Weight is a problem.
16. Maintenance is high.
17. Maintenance is low.
18. It is still in the experimental stages.
19. The medium is inexpensive.
20. Heating of domestic water is easily integrated into the system.

ANSWERS TO ASSIGNMENT SHEET AND UNIT TEST V.

Answer to Assignment 1

Masonry surfaces and concrete absorb whatever heat is available. In a basement there is no insulation between the wall and the ground , and the heat will move out into the surrounding dirt and thus not be available to reheat the interior space. The mass of the concrete and masonry in an industrial building may be so great that heat cannot be supplied in a sufficient quantity. The heat provided, rather than heating the air, is absorbed by the masonry and concrete.

Answer to Assignment 2

It would take large amounts of energy to heat the interior spaces which are enclosed by cement and masonry because the available heat will be absorbed by these surfaces.

Answer to Assignment 3

Rock Storage

Advantages	Disadvantages
Large heat capacity	Bulkiness of the rocks
Can store heat at high temperatures	Heaviness of the rocks
Low maintenance	Requires large space
No leakage	
Inexpensive	
Used with air, exchange is simple	

Answer to Assigment 4

Water

Advantages	Disadvantages
Highest heat capacity per pound	Storage tanks are expensive
Water is inexpensive	Freezing
Heat transfer to water is more efficient than to rock	Corrosion
	Leakage
Heating of domestic water is easily integrated	Heat exchangers

Answers to Unit Test 1

a, b

Answers to Unit Test 2

a. F

b. T

C. F

d. T

e. T

f. F

g. F

h. F

i. T

j. T

Answers To Unit Test 3

A. Advantages 5, 7, 9, 11, 12, 17, 19

Disadvantages 13, 15

B. Advantages 2, 14, 19, 20

Disadvantages 4, 6, 8, 10,15,16

C. Advantages 1, 5*

D, Disadvantages 3, 6*, 8*, 10, 18

* Answer may be omitted.

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UNIT V1

DISTRIBUTION

UNIT OBJECTIVE

After completion of this unit, the participant should be able to explain the methods available for transporting the thermal energy to the point of use. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the participant should be able to

1. Match terms relating to heat transfer and distribution with the correct definitions.
2. Recognize correct statements referring to the distribution component.
3. Identify correct statements about distribution processes which make use of the flow of gasses.
4. Identify correct statements about distribution processes which make use of radiation.

1. TERMS AND DEFINITIONS

Conduction-Heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Convection-when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Radiation-any object which is warmer than its surrroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Change-of-state-the physical form of matter changes from solid to liquid to gas. For example, water can be changed to a solid (ice) or gas (steam). When changes of state occur, energy is either used or released in the process.

Emittance-radiation discharged from a surface; the reradiation of heat.

2. THE DISTRIBUTION COMPONENT

Generally speaking, methods by which thermal energy from storage or collector can be distributed to point of use are gas flow and radiation. Within each category there are several techniques by which the distribution of energy to occupied spaces can be accomplished. Some involve mechanical and electrical equipment and processes while others utilize natural convection and radiation. The manner in which solar radiation is collected and stored will usually determine the means of distribution. For example, in a flat-plate collector which employs air as the heat-transport medium is used to capture solar radiation and a rock pile is used to store the heat, distribution is usually accomplished by air.

3. GAS FLOW DISTRIBUTION

Natural Convection

Natural convection is the circulatory motion of air caused by thermal gradients without the assistance of mechanical devices. An example of convection is the motion of smoke towards room lamps--the hot air generated by the lamp rises because it is less dense, and cooler air moves in to replace it.

Natural convection is a useful means of distributing solar thermal energy because it requires no mechanical or electrical input. However, for this same reason, careful attention to design is required to maintain proper control of convective distribution methods. The placement of solar collectors, storage, interior and exterior walls and openings is extremely important for the successful operation of convective distribution.

Adapted from AIA Research Corportation, Solar Dwelling Design Concepts, Washington, D. C. : Government Printing Office, May 1976, pp. 30-31.

The operation cycle of natural convective distribution is quite simple. Heat from the collector or storage is supplied to the living space. This process is controlled by the collector or storage design or by wall or floor vents. As the hot air rises to displace cooler air, convection currents similar to those causing winds occur, and the air is distributed through the space. The air is cooled, becomes dense, and falls toward the floor, where it is captured by cool air return vents, passed through the collector and storage and once again distributed. The cycle will continue as long as there is a temperature difference between the collector/storage components and the room air. When the convection heating cycle is not desired, in the summer for instance, the warmer air may be vented to the exterior.

Forced Air

A forced air system relies on mechanical equipment and electrical energy for the distribution of thermal energy. Design for solar systems is much the the same as for conventional forced air systems. However, because solar-produced temperatures in storage are often relatively low, distribution ducts and vents must normally be larger than those used in conventional heating/cooling systems. Therefore, to achieve maximum efficiency in a solar system, careful attention to the design of air distribution throughout a dwelling is required.

Forced air distribution for solar systems is similar to conventional air distribution. Air from either the collector or storage is blown through ducts to the occupied spaces. The type of solar collector or storage is not the determining factor for selection of a forced air ducted system: the system is adaptable to rock, water, or change-of-state storage components. For rock

and containerized change-of-state storage, air is simply blown through the storage to ducts which supply the dwelling spaces. In the case of water storage, a heat exchanger is required to transfer heat from the liquid to air, which is distributed to dwelling spaces.

4. RADIATION

Natural Radiation

Radiation occurs as a natural phenomenon. It is the direct transfer of energy by little energy packets, called photons, and occurs without the need for any intervening substance such as air or water. All of the energy from the sun reaches the earth by radiation through empty space. Thus, radiation can take place without the assistance of mechanical devices. The radiation properties of the emitting and absorbing surfaces, which are influenced by their temperature, will determine the rate of heat flow between the two surfaces.

Unlike natural convection, which is dependent on differential air temperatures for distribution, natural radiation is dependent on differential surface temperatures. An example of natural radiation is the sun warming a greenhouse on a cold day. The radiant energy is transferred directly to the greenhouse surfaces and is not significantly affected by the cool temperature of the surrounding air. Natural radiation is particularly useful for collector or storage systems which are directly exposed to the occupied spaces. The captured energy can be emitted by natural radiation directly to the room's surface. The walls, floors, and ceiling of a dwelling are used to collect and/or store thermal radiation. The energy will radiate directly to a room's other cooler surfaces.

Forced Radiation

Forced radiant distribution relies on the transfer of heat to air in the occupied spaces by radiation and convection from circulating hot water liquid flow through tubes. For cooling, the forced radiant system is generally used

in conjunction with a refrigeration unit which passes chilled water through a fan coil unit located at the point of distribution. A blower is used to force air through the cooled fan coil unit and into occupied spaces.

The piping for the radiant system may be located in the ceiling, floor, or along the wall in fin tube baseboard units. The only significant alteration required of conventional radiant systems for use by solar systems is the enlargement of the radiating surfaces—larger fin tubes or closer spaced ceiling or floor coils—because of lower temperatures from storage.

Unit Test--DISTRIBUTION

1. Match terms with the correct definitions

____A. Convection	1. Physical form of matter is transformed from a liquid to a solid.
____B. Radiation	2. The reradiation of heat
____C. Change-of-state	3. Because a hot surface is separated from a cool surface by a thin air space, moving air currents are established.
____D. Emittance	4. Heat waves are transmitted from a warm surface to its surroundings.
____E. Conduction	5. Heat transfer by direct physical contact of two materials

2. Mark with a "T" those statements which are true, and identify with "F" those statements which are not true.

____A. There are four general methods used for distributing the thermal energy from storage or the collecting surface to the point of use.

____B. Pumps must always be used to force a heated liquid or air through the distribution system in solar heating systems.

____C. The heat transfer medium may determine the type of distribution system used.

____D. The way in which solar radiation is collected and stored may determine how the thermal energy is distributed.

____E. Radiation is the only method for distributing thermal energy.

____F. Natural methods for distributing thermal energy are convection and radiation.

____G. The distribution component of a solar energy system can be accomplished by using mechanical equipment and processes.

____H. Natural heat transfer principles cannot be applied in distributing thermal energy to a house.

3. Indicate which of the following statements apply to natural convection and which apply to forced air. Not all statements may apply.

A. Natural Convection_____

B. Forced Air_____

1. The two surfaces must be in direct physical contact for heat transfer to occur.

2. When the heating cycle is not desired, the warm air can be vented to the exterior of the building.

3. Distribution is similar to that used in conventional heating systems.

4. No mechanical or electrical input is required if the distribution system is designed carefully.

5. Distribution is controlled by the collector or storage design or by wall or floor vents.

6. Vents and ducts must be much larger than in conventional systems because temperatures are relatively low.

7. The system is adaptable to any kind of storage component.

8. Distribution will occur only if the sun is not shining directly on the surface.

9. Distribution will continue as long as there is a difference in temperature between the collector/storage components and the room air.

4. Indicate which statements below refer to Forced Radiation (FR) and which refer to Natural Radiation (NR). Some statements may refer to both; some may refer to neither method of distribution.

_____A. Radiating surfaces, such as fin tubes or ceiling or floor coils, must be larger than in conventional systems.

_____B. The walls, floors, and ceiling may be used not only to collect and store the energy but also in the distribution of the energy.

_____C. Heat flow is determined by differences in temperature of two surfaces.

_____D. Hot water is circulated through tubes in the floor or ceiling.

_____E. Heat flow is partially aided by air temperature differentials.

ANSWERS TO UNIT TESTS--DISTRIBUTION

Answers to Unit Test 1

A. 3

B. 4

C. 1

D. 2

E. 5

Answers to Unit Test 2

A. F

B. F

C. T

D. T

E. F

F. T

G. T

H. F

Answers to Unit Test 3

A. Natural Convection 2, 4, 5, 9

B. Forced Air 3, 6, 7

Answers to Unit Test 4

A. FR

B. NR

C. FR, NR

D. FR

E. FR

UNIT VII

REPRESENTATIVE SOLAR ENERGY SYSTEMS

FOR HEATING HOMES

UNIT OBJECTIVE

After completion of this unit, the participant should be able to describe some representative solar energy systems. This knowledge will be evidenced by scoring 85 percent on the unit test.

SPECIFIC OBJECTIVES

After completion of this unit, the participant should be able to

1. Match terms with their correct definitions.

2. A. Name and describe the components of a warm-water flat-plate system.

   B. Identify advantages and disadvantages of the system.

3. A. Name and describe the components of a warm-air flat-plate system.

   B. Identify advantages and disadvantages of the system.

4. A. Name and describe the components of a warm-water concentrating system.

   B. Identify advantages and disadvantages of the system.

5. A. Name and describe the components of a warm-air passive system.

   B. Identify advantages and disadvantages of the system.

1. TERMS AND DEFINITIONS

Heat transfer medium, or heat transport fluid--a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use.

Auxiliary energy system--in addition to the solar energy system, an additional heating system may be installed. These additional systems can range in complexity from an air-tight, woodburning stove to a gas-fired furnace.

Direct radiation--direct or parallel rays from the sun.

Diffuse radiation--the solar radiation striking the surface of the earth after its direction has been changed by reflection and scattered by particles in the atmosphere--nondirectional rays.

Thermosyphoning--the principle that heated gasses and liquids rise naturally has been applied as a means of heat transport in passive solar energy systems. Heat built up within a wall or roof structure can be drawn off to heat interior spaces.

Convection--when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Radiation--any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Conduction--Heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Information Sheet*

2. WARM-WATER FLAT-PLATE SYSTEM

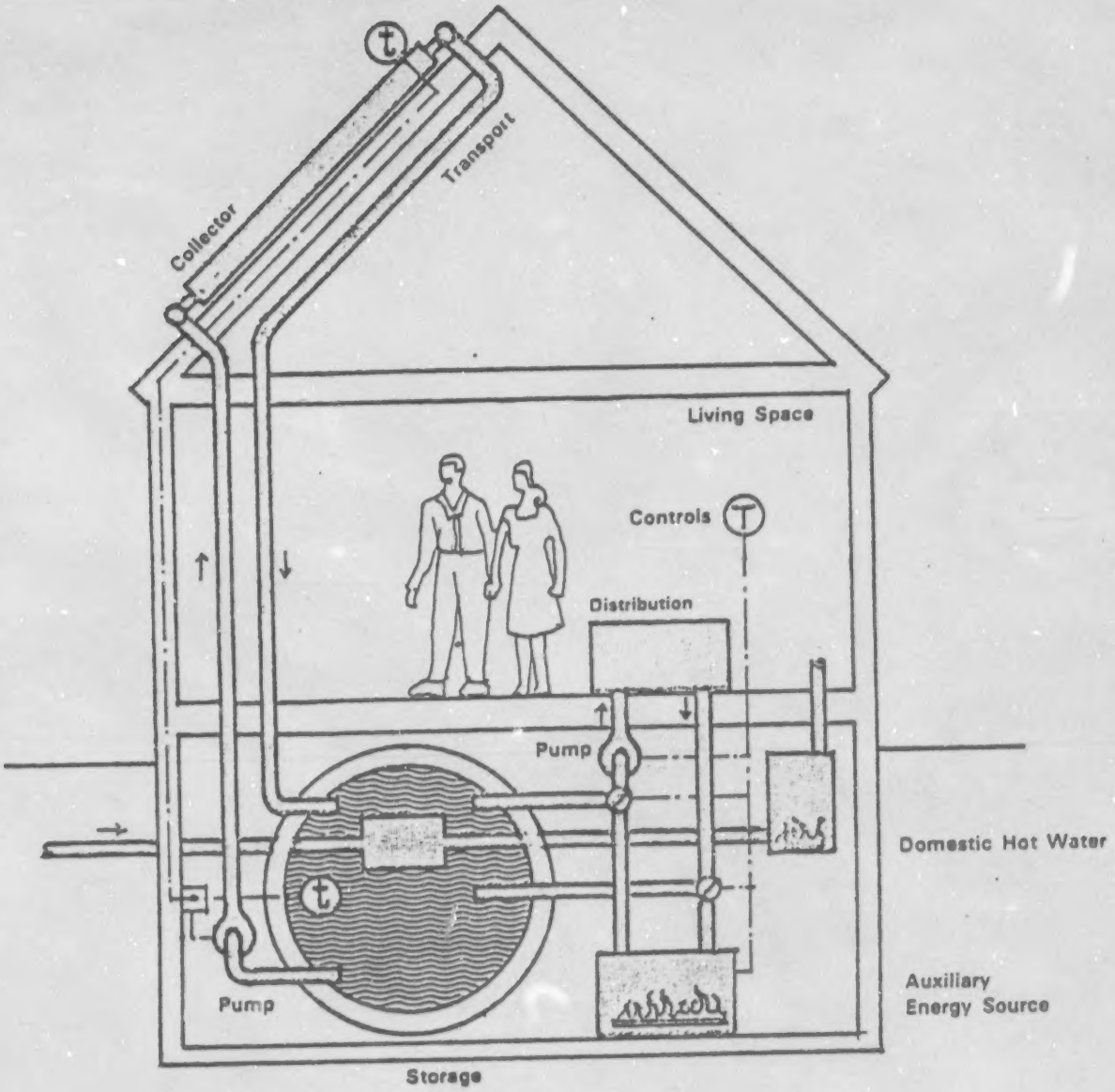
Solar heating using water as the heat transfer and storage medium is a system which is in common use today. The basic components of a typical water system consist of a collector; storage; a system of piping, pumps, and controls for circulating water from storage through the collector; and a distribution network for transferring stored heat to the dwelling space. The relationship of the various components of a warm-water solar system is diagrammed in Transparency 7.1.

Component Description and Operation

Collector. The liquid-cooled flat-plate collector has a flat absorbing surface integrated with transfer fluid piping which collects both direct and diffuse radiation. Energy is removed from the collector by a liquid flowing through conduits in the absorber plate. The transport fluid is pumped to storage, where the heat is transferred to the storage medium (water in this case) and then returned to the collector to absorb more heat. Generally, the transfer fluid is circulated through the collector only when the absorbing surface is hotter than storage (except in instances when snow has covered the collector surface and the heated transport fluid is circulated through the collector to melt it).

Storage. Storage consists of either a concrete or a steel tank located near or beneath the building (access should be provided). The tank should

*Adapted from AIA Research Corporation, Solar Dwelling Design Concepts, Washington, D.C., Government Printing Office, May 1976, pp. 32-38.



Transparency 7.1: Schematic Diagram of Warm-Water Flat-Plate System.

be insulated to minimize heat loss. A concrete tank should be lined with a leak-proof material capable of withstanding high storage temperatures for extended periods without deterioration. Heat from the collector is transferred to storage by a heat exchange coil passing through the storage tank. Coil length and size is dependent on expected collector operating temperatures.

Distribution. The distribution system consists of a pump and pipes which deliver heated water to the occupied spaces. A thermostat controls the operation of water flow or fan coil unit use in each room or dwelling. Baseboard heaters (convectors) require careful evaluation when not used in conjunction with a fan coil unit. Liquid-cooled flat-plate collectors seldom deliver water above 150° F in winter operation without auxiliary energy or reflected surface focusing. For this reason most warm water distribution systems use fan coil units or enlarged convectors.

Energy is transported away from the collector to storage by water or a water-antifreeze solution. Liquid transport fluids should be carefully evaluated before selection. The liquid must absorb heat readily at various collector temperatures and easily give up heat to the storage medium. Additionally, the liquid should not be corrosive to the system components, toxic, or susceptible to freezing or boiling.

A gas-fired conventional boiler is integrated with the solar system to provide an auxiliary energy supply should the solar system fail to function or not meet the dwelling's heating requirement. The distribution piping is run through the boiler where an energy boost may be supplied when temperatures from storage are not sufficient to heat the dwelling adequately.

Domestic hot water piping is run through the central storage tank prior to passing through a conventional water heater. Storage heat is transferred

to the hot water piping, thereby either eliminating the need for additional heating or substantially reducing the energy required to raise the water to the needed distribution temperature. The domestic water heating system may operate independent of the space heating system. This is very useful for summer months when space heating is not required.

Advantages of Warm-Water Flat-Plate Systems

1. They have repeatedly been proved to work well.
2. Water is a cheap and efficient heat transfer and storage medium.
3. Piping, as opposed to ductwork, uses little floor space, is easily interconnected, and can be routed easily to remote places and around corners.
4. The circulation of water uses less energy than the circulation of air with corresponding heat content.
5. Much less heat exchanger area is required than with an air system.

Disadvantages of Warm-Water Flat-Plate Systems

1. High initial cost, particularly when expensive prefabricated collectors are employed. With the use of large areas of lower-efficiency collectors, the total system cost may be lowered considerably.
2. Care must be taken to prevent the occurrence of corrosion, scale, or freeze-up capable of causing damage or blockage.
3. Leakage anywhere in the system can cause a considerable amount of damage to the system and to the dwelling.
4. Contamination of the domestic hot water supply is possible if a leak allows treated water storage to enter the domestic water system.

3. WARM-AIR FLAT-PLATE SYSTEM

Warm-air systems differ from warm-water systems in that air is used to transfer heat from collector to storage. The storage medium can be water, but more typically rock piles are used for warm-air systems. Heat, stored in the rock pile, can easily be distributed to the dwelling space by a forced air system. One possible arrangement of a warm-air system is diagrammed in Transparency 7.2.

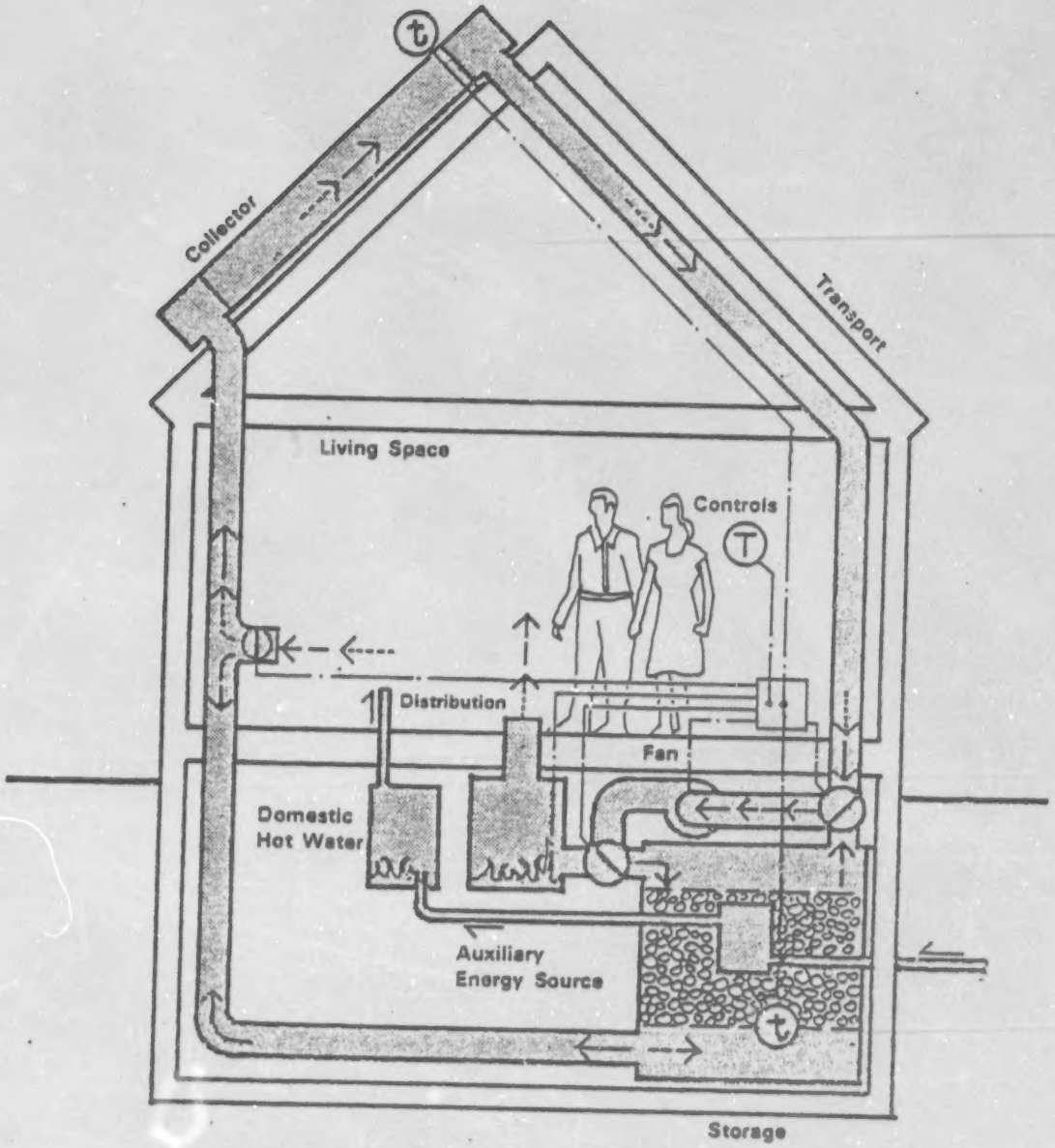
Component Description and Operation

Collector. The air-cooled flat plate collector has a solid absorbing surface and collects both direct and diffuse radiation. Energy is removed from the collector by air flowing in ducts beneath the absorber plate. As shown in the diagram, the system may be operated in four different modes:

1. heating storage from collector
2. heating house from collector
3. heating house from storage
4. heating house from auxiliary energy system

The four modes of operation are regulated by several sets of dampers. One set of dampers will direct air flow from the collector into storage or directly into the occupied spaces while another set will regulate air flow from storage to the occupied spaces. The dampers may be adjusted by manual or automatic controls. During modes two and three, an energy boost may be supplied to the warm air by the auxiliary energy system before the air is distributed to the occupied space. The amount of the energy boost is determined by the temperature of the air passing through the auxiliary heater and the amount of heat required at the point of use.

Storage. Storage consists of rocks about two inches in diameter, contained in a concrete bin in a basement area or underground beneath the building. The container is insulated on the earth sides to reduce heat loss. The storage capacity should be sufficient to provide several days of winter heating.



Transparency 7.2: Schematic Diagram of Warm-Air Flat-Plate System.

Because the temperatures in rock storage are typically highly stratified from inlet to outlet, the air flow providing heat to storage should be from top to bottom. This insures that the temperature of air returning to the collector from the storage is as low as possible, thereby increasing collector efficiency. The air flow, when removing heat from storage, should be in the opposite direction to insure that air returning to the rooms is as warm as possible.

Distribution. The hot air distributed to the rooms comes either directly from the collectors or from storage. The ducting required to conduct the air from the collectors to storage is extensive when compared to analogous piping requirements for liquid-cooled collectors. Two blowers are required to distribute air throughout the system.

Almost any type of auxiliary energy system may be used in conjunction with a solar system. The auxiliary system may be completely separate or fully integrated with the solar heating/cooling system. However, in most cases it makes economic sense to integrate the back-up system with the solar system. This may mean running the distribution component from heat storage to the occupied space through the auxiliary system where an energy boost may be supplied when storage temperatures are low. Heat from storage may be used in conjunction with a heat pump. The heat pump, a device which transfers heat from one temperature level to another by means of an electrically driven compressor, utilizes the solar heat available from storage to supply necessary heat to the occupied space. The advantage of the heat pump/solar system integration is the reduction of electrical energy required by the heat pump because of heat supplied by solar storage. Also, the heat pump is the most efficient device presently available for extracting and transferring electricity into heat.

Piping for the domestic hot water is run through the rock pile storage bin. As a result, the domestic hot water is preheated before passing through a conventional water heater, thus reducing the water heater's energy requirement.

Advantages of Warm-Air Flat-Plate Systems

1. Capital cost tends to be lower than a water system of the same capacity.
2. There is no problem with corrosion, rust, clogging or freezing.
3. Air leakage does not have the severe consequences of water leakage.
4. Domestic hot water supply is not subject to contamination by leakage from heat storage, as in the water system.

Disadvantages of Warm-Air Flat-Plate Systems

1. Ductwork risers occupy usable floor space and must be aligned from floor to floor.
2. Air, having a lower thermal storage capacity than water, requires correspondingly more energy to transfer a given amount of heat from collector to storage, and from storage to occupied spaces.
3. Air collectors and storage may need frequent cleaning to remove deposits of dust (filters may solve this problem).
4. Air systems require a much larger heat exchange surface than liquid systems.

4. WARM-WATER CONCENTRATING SYSTEM

Solar systems with concentrating collectors have not been extensively used for the provision of space heating or cooling. The absence of such equipment from the market, the high cost and uncertain reliability of tracking or concentrating equipment under freezing rain, ice or wind and snow conditions have been the primary reasons for their limited use. However, they do offer advantages over flat-plate collectors--primarily the generation of high temperatures to operate heat driven cooling systems.

Representative solar system three utilizes a linear concentrating collector. The system is diagrammed in Transparency 7.3.

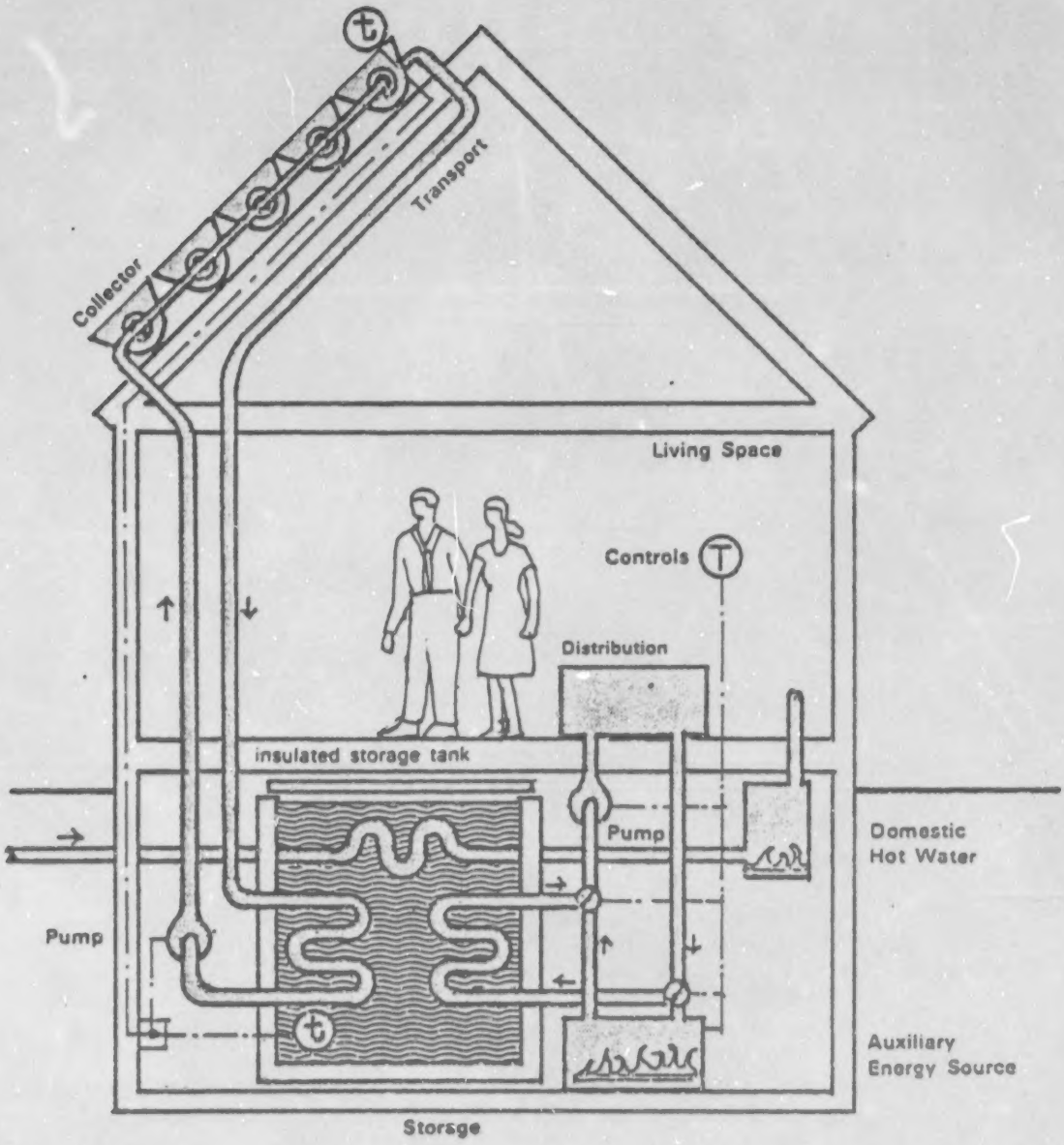
Component Description and Operation

Collector. The collector is a linear concentrator with a glass-enclosed pipe absorber. The collector captures only direct radiation and is, therefore, limited to climatic regions with considerable sunshine and direct radiation in winter. However, where applicable the linear concentrating collector offers considerable economies over flat-plate collectors since the necessary absorber area is reduced and the assembly is often simpler to construct.

The absorber pipe is a black metal tube within a glass enclosure under vacuum to reduce convection and radiation losses. Radiation is focused on the absorber by a trough-shaped reflector surrounding the pipe.

Storage. Storage consists of a steel tank or a lined concrete block enclosure filled with water. Again, the storage unit should be insulated to minimize heat loss. As with most all solar storage techniques, special structural support will be required if the storage tank is to be located in the dwelling.

Distribution. The distribution system is by heated water to baseboard convectors. Heat is removed from storage by liquid-to-liquid heat exchanger. The heated water is pumped to baseboard convectors located throughout the building. If storage is below a preset minimum temperature, the pump continues



Transparency 7.3: Schematic Diagram of Warm-Water Concentrating System.

to operate with a conventional oil or gas-fired furnace assist in the liquid distribution.

As shown in the system diagram, collector fluid transport is by means of a pump which causes the fluid to flow through the absorber and into the storage heat exchanger, from which energy is removed and transferred to storage. The working fluid should be a heat transfer medium which has excellent transport properties and a boiling point above the expected operating temperature of the collector.

Domestic hot water piping is run through a heat exchanger in storage, thus preheating the water, before it proceeds to a conventional water heater which also provides storage. The water heater may or may not supply a boost to the water depending on its temperature.

Advantages of Warm-Water Concentrating Systems

1. Potential for more than double the temperatures of either air or water flat-plate collectors (particularly useful for solar cooling).
2. Total absorber area needed is substantially smaller than flat-plate collectors.
3. Collector forms lend themselves to mass production techniques.
4. Water requires less piping and storage space than air.
5. Water is a cheap and efficient heat transfer and storage medium.

Disadvantages of Warm-Water Concentrating Systems

1. Capital cost of collectors at present is greater than either air or water flat-plate collectors.
2. Concentrating collectors may present problems of operation, reflecting surface durability, and structural mounting.
3. Leakage at flexible absorber connections may present possible problems.
4. Climatic applicability for winter space heating is limited because only direct radiation can be collected.

5. WARM-AIR PASSIVE SYSTEM

The passive system described here is one possible concept among many. It makes use of extensive south-facing glazing with an intermediate collection/storage wall between the glazing and the occuplied space. It relies in part on thermosyphoning. Diagrammatically, the passive system can be represented as illustrated in Transparency 7.4.

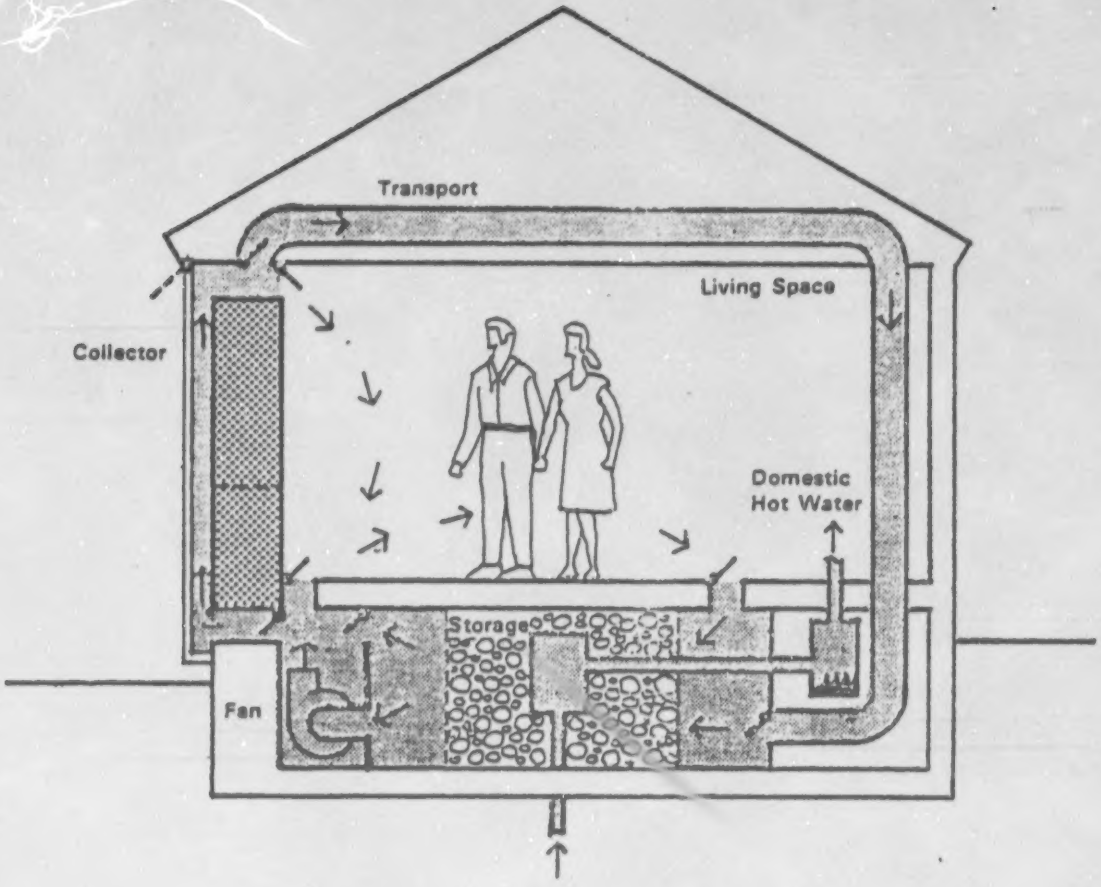
Component Description and Operation

Collector. The passive collector, made up of a massive south-facing wall of either concrete or masonry separated by an air space from an outer wall of glass, captures direct, diffuse, and reflected solar radiation. With the use of automatic or manually operated dampers and vents, the system may operate in four modes.

1. natural ventilation--no collection
2. house heating from collector
3. storage heating from collector
4. house heating from collector and storage

When no collection or heat distribution is required, the vents and dampers may be opened to provide natural ventilation and removal of heat striking the collector. The space may be heated directly from the collector by closing the storage vent duct, thus forcing the heated air into the occupied space. Once sufficient heat has been transferred to the space, the storage vent may be opened and heated air from the collector transmitted to storage. If heat is required at a later time, the storage vent may be opened to allow stored heat to enter the occupied space.

Storage. The system employs several storage concepts. The exposed masonry wall which the radiation strikes acts as a storage element. The warmed masonry surface transmits collected heat to the occupied space by radiation. The second storage element is a rock pile located beneath the occupied space. Insulation is placed between the rock pile and floor surface to avoid over-



Transparency 7.4: Schematic Diagram of Warm-Air Passive System.

heating the space. Water or containerized salts (change-of-state storage) could also have been used as the storage medium.

Distribution. Heat is distributed to the occupied spaces from the collector or storage component. Ducting is required to transport the heated air from the collector to storage, and a small fan may be necessary to circulate this air. Heat is distributed to the space by convection from the collector and/or storage, by radiation from the collector and surrounding surfaces, and to a small degree, by conduction from the collector and surrounding surfaces.

Domestic water heating is not directly integrated in the solar space heating system. However, a storage tank or the domestic hot water piping may be placed in the rock pile storage to preheat the water before it passes through a conventional electric or gas water heater.

Advantages of Warm-Air Passive Systems

1. A system with electrical controls can be designed to operate manually in a power failure.
2. Cost should be reduced through simpler technology and elimination of a separate collector.
3. Collector serves multiple functions (i.e., can be a wall or roof).

Disadvantages of Warm-Air Passive Systems

1. May not be cost effective relative to warm air or water flat-plate collector systems.
2. In many cases, require automatic or manual insulating devices which are expensive and may require life style modification.
3. Larger unobstructed area needed to the south of the house for a vertical passive collector than for a roof collector.
4. In some climates and for some passive systems, low winter sun angles may be disturbing to the occupants.
5. Potential problems of occupant-privacy for passive systems with large expanses of south-facing glass.
6. Potentially large nighttime thermal losses from collector if not properly insulated.

Activity Sheets

Activity 1

A. From the matrix below (Transparency 7.5), choose components and a heat transport fluid for a hypothetical active solar energy system. Anticipate possible advantages or disadvantages which might be associated with the system. Consider some systems which were not discussed in the information section of this unit.

Components			Heat Transfer Fluid: Air	Heat Transfer Fluid: Liquid
Collector	Flat-Plate	Air Open H_2O Liquid		
	Concentrating	Linear Circular		
Storage	Water			
	Rock			
	Change-of-State			
Distribution	Forced Liquid (Radiation)			
	Forced Air			

Transparency 7.5

B. A system is defined as "a grouping together of parts that operate together for a common purpose" (Forrester, 1972, p. 1-1). In performing step A, above, did you find that choosing one component restricted your choice of the other components? In your own words, explain why your choice might become more restricted as each component is added.

Activity 2

A similar matrix for components of a passive system are shown below.

Components		Heat Transfer Medium: Air	Heat Transfer Medium: Fluid
Collector	South-facing Windows Clerestory Windows Trombe Wall Water Ponds Greenhouse		
Storage	Floor Walls Water Ponds		
Distribution	Convection Radiation Conduction		

Why cannot this matrix be used in a manner similar to the matrix in Activity 1?

UNIT TEST--REPRESENTATIVE SOLAR ENERGY SYSTEMS

1. Match terms with the correct definitions

_____A. Heat transfer medium

_____B. Auxiliary energy system

_____C. Radiation

_____D. Direct radiation

_____E. Diffuse radiation

_____F. Thermosyphoning

_____G. Convection

_____H. Conduction

1. Nondirectional rays from the sun
2. A means of heat transport based on the principle that heated gasses and liquids rise naturally
3. A liquid or gas which absorbs heat readily--is used to move heat away from the collector.
4. Moving air currents carry heat from a hot to a cold surface.
5. Parallel rays from the sun
6. Heat flows from one material to another with which it has direct physical contact because of molecular vibration.
7. Energy is transmitted by photons from a warmer object to cooler surroundings.
8. Supplementary heat source other than solar.

2. A. Name and describe briefly the components of a warm-water flat-plate system.

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-water, flat-plate system. Not all statements will be applicable (NA).

_____1. Leakage could be a problem.

_____2. Corrosion could be a problem.

_____3. Can use only direct radiation.

_____4. Circulation of water uses less energy than the circulation of air with the same amount of heat content.

_____5. Freezing is a potential problem.

_____6. Initial cost is high.

_____7. Less heat exchanger area is required than with an air system.

_____8. Piping takes up less space than does duct work.

_____9. The reflector surface must be kept clean.

_____10. Water is a cheap and efficient heat transfer and storage medium.

3. A. Name and describe briefly the components of a warm-air flat-plate system.

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-air flat-plate system. Not all statements will be applicable (NA).

_____1. Leakage is not a problem.

_____2. Corrosion is not a problem.

_____3. Only direct radiation can be used.

_____4. The collectors and storage may need frequent cleaning.

_____5. Cost of equipment tends to be lower than with a water system of the same capacity.

_____6. More energy is required to transfer heat if air is used as the heat transport medium.

_____7. Ductwork requires a greater amount of space than does piping for fluids.

_____8. The reflector surface must be kept clean.

_____9. A larger heat exchange surface is needed for air than is needed for liquids.

_____10. The system does not require complicated controls.

4. A. Name and describe briefly the components of a warm-water concentrating system.

1. _____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-water concentrating collector. Not all statements will be applicable (NA).

_____1. Leakage may present problems.

_____2. The reflector surface must be kept clean.

_____3. Water is a cheap and efficient heat transfer and storage medium.

_____4. Only direct radiation can be collected.

_____5. Higher temperatures can be obtained than can be obtained with flat-plate collectors.

_____6. The absorber area needed is smaller than that needed with flat-plate collectors.

_____7. Ductwork must be large.

_____8. Costs could be lower because the collector forms lend themselves to mass production techniques.

_____9. At present, concentrating collectors are more expensive.

_____10. In climates with many sunless days, the system may not be applicable.

5. A. Name and describe the components of a warm-air passive system.

1. _____

_____

_____

_____

2. _____

_____

_____

_____

3. _____

_____

_____

_____

B. From the following list, identify some advantages (A) and disadvantages (D) of a warm-air passive system. Not all statements will be applicable (NA).

_____1. Automatic or manual insulating devices are expensive.

_____2. Life style may need to be modified.

_____3. Cost should be reduced through simpler technology.

_____4. Elimination of separate collector should reduce cost.

_____5. A vertical passive collector will require a larger unobstructed area for access to the sun.

_____6. Ductwork is expensive and takes up a large amount of space.

_____7. Leakage may be a problem.

_____8. May not be cost-effective relative to air- or liquid-cooled collectors.

_____9. Collector serves multiple functions.

_____10. Large expanses of south-facing glass may cause problems about occupant-privacy.

ANSWERS TO UNIT TEST--REPRESENTATIVE SOLAR ENERGY SYSTEMS

Answers to Unit Test 1

A. 3

B. 8

C. 7

D. 5

E. 1

F. 2

G. 4

H. 6

Answers to Unit Test 2

A. 1. Liquid-cooled flat-plate collectors have a flat absorbing surface to absorb both direct and diffuse radiation. The heat transfer fluid is piped across the absorbing surface.

2. Hot water is stored in an insulated concrete or steel tank. Heat from the collector is transferred to storage by means of a heat exchange coil.

3. Distribution is accomplished by pumping the hot water from storage through pipes to baseboard heaters.

B. 1. D

2. D

3. NA

4. A

5. D

6. D

7. A

8. A

9. NA

10. A

Answers to Unit Test 3

A. 1. The air-cooled flat-plate collector has a solid absorbing surface to collect direct and diffuse radiation. Air is pumped through the collector.

2. The hot air is blown into the rock storage. The rocks are about 2 inches in diameter and the container is insulated.

3. The hot air is pumped through ducts to the rooms.

B. 1. A

2. A

3. NA

4. D

5. A

6. D

7. D

8. NA

9. D

10. NA

Answers to Unit Test 4

A. 1. The linear collector captures only direct radiation, which the reflecting surface concentrates on a glass-enclosed pipe. The pipe, usually painted black, is the absorber. The heat transfer medium circulates through the pipe.

2. The storage unit is a well-insulated, leak proof tank for storing hot water.

3. Distribution is accomplished by pumping the heated water to base-board heaters located throughout the building.

B. 1. D

2. D

3. A

4. D

5. A

6. A

7. NA

8. A

9. D

10. D

Answers to Unit Test 5

A. 1. The collector is a massive south-facing wall of masonry or concrete separated by an air space from an outer wall of glass. It will capture reflected, direct, and diffuse radiation (a Trombe Wall).

2. Storage is the exposed wall, a rock pile under the floor, and other internal surfaces which absorb heat radiated from the south wall.

3. Distribution is by convection, radiation, and conduction. Also, heated air is transported through ducts to storage and from storage to the living space. A small fan may be needed to assist natural means of heat transfer.

B. 1. D

2. D

3. A

4. A

5. D

6. NA

7. NA

8. D

9. A

10. D

GLOSSARY

Active Solar Energy System--thermal energy is transported from the collectors to storage and then to the distribution system in a regulated way, using mechanical pumps and thermal controls.

Air-Cooled Collector--a type of flat-plate collector in which air is used as the heat transport medium.

Angle of Declination--see Declination angle.

Angle of Incidence--see Incidence angle.

Azimuth--an angle obtained by measuring from due south and rotating until facing the sun.

Beadwall--a patented insulated window in which polystyrene beads are blown into or pulled out of a space between two sheets of glass or plastic by a vacumn-driven system.

Biomass conversion--energy from the sun is stored through the process of photosynthesis in plants, i.e., in organic material. Chemical processes can be used to change the organic material to simpler forms with an accompanying release of energy.

Change-of-state--the physical form of matter changes from solid to liquid to gas. For example, water can be changed to a solid (ice) or a gas (steam). When changes of state occur, energy is either used or released in the process.

Circular Concentrating Collector--a type of concentrating collector which is circular in shape so that the affected solar radiation is focused on an absorbing surface.

Clerestory Window--a south facing window in the wall of a room which rises above an adjoining roof; the window can be used to admit solar radiation.

Collector--the component in a solar energy system which receives solar radiation and converts it to heat.

Collector-tilt--the angle measured from the horizontal at which a solar collector is tilted to face the sun for better performance.

Concentrating Collector--a class of collectors which use reflectors to focus solar radiation on a small area.

Conduction--Heat flows through different materials at varying rates. Copper is an excellent conductor of heat; insulating materials are poor conductors. Heat transfer by conduction occurs only when two surfaces are in direct physical contact because heat transfer is caused by molecular scale vibration.

Convection--when two surfaces, one hot, the other cold, are separated by a thin layer of air, moving air currents are established that carry heat from the hot to the cold surface. In convection, heat transfer is by large-scale fluid motion.

Declination angle--the angle between the plane of the earth's rotation around the sun and the earth's equatorial plane in a direction facing the sun.

Diffuse radiation--the solar radiation striking the surface of the earth after its direction has been changed by reflection and scattered by particles in the atmosphere--nondirectional rays.

Direct radiation--direct or parallel rays from the sun.

Distribution--the component in a solar energy system whereby the thermal energy in storage is made available at the point of use.

Emittance--radiation discharged from a surface, the reradiation of heat.

Energy--the ability to do work.

Fenestration--the placement, size, and design of windows and doors in a building.

Flat-Plate Collector--a class of collectors so named because of the large surface area exposed to the sun.

Heat-transport fluid--a liquid or gas which absorbs heat efficiently and moves the heat away from the collector to storage or to point of use. Also called heat transfer medium.

Incidence Angle--the angle between the line for direct rays and a line perpendicular to the irradiated surface.

Insolation--the amount of solar radiation actually striking the surface of the earth.

Irradiation--exposure to radiant energy.

Latitude--the angular distance north or south from the earth's equator measured through 90°.

Linear Concentrating Collector--a type of concentrating collector, oblong in shape, which focuses the reflected radiation onto a tube through which the transport medium is circulated.

Liquid-Cooled Collector--a type of flat-plate collector in which the liquid used as the heat transport medium, is piped through the collector box.

Nonrenewable energy source--a substance found in nature which cannot be replenished and which can be used to obtain energy in some form. Coal, gas, uranium are examples of nonrenewable energy sources.

Open-water collector--a type of flat-plate collector in which the heat transport medium, ususally water, is trickled down grooves rather than pip d through the collector.

Passive Solar Energy System--heat is transported by natural means, and the components are typically integrated into the basic design of the dwelling, so that few, if any, mechanical devices are needed in the system.

Photovoltaic--direct conversion of the sun's energy to electricity.

Radiation--any object which is warmer than its surroundings transmits heat waves (similar to light waves, but invisible) and, thus, emits energy. Heat transfer occurs by photons.

Renewable energy source--a substance which occurs in nature and the supply of which cannot be depleted by use.

Solar Altitude--the angle of elevation of the sun above the horizon.

Solar Constant--the amount of solar energy striking the outer atmosphere of the earth varies only slightly and can be treated as a constant.

Solar Energy System--a grouping of parts designed to use energy from the sun. The parts, or components, are the collector, storage, and distribution. One or several components may themselves be sub-systems, i.e., systems within the system.

Solar noon--that time of day when the azimuth angle is 0°, when the sun is due south of an observer.

Storage--the component in a solar energy system which retains the solar energy which has been collected for later use either at night or on cloudy days.

System--"a grouping together of parts that operate together for a common purpose" (Forrester, 1972, p. 1).

Thermosyphoning--the principle that heated gasses and liquids rise naturally has been applied as a means of heat transport in passive solar energy systems. Heat built up within a wall or roof structure can be drawn off to heat interior spaces.

Transmittance--the fraction of solar radiation which having entered a layer of absorbing material, flows to its further boundary.

Trombe Wall--a type of passive collector which makes use of a massive masonry wall, painted black and placed behind a south-facing wall of glass. Air trapped between the wall and the glass is heated, moves up over the wall and into the interior space.

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